DOCUMENT RESUME

ED 085 219 SE 016 175

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TITLE A Summary of Research in Elementary, Secondary, and College Levels of Science Education for 1970.
INSTITUTION ERIC Information Analysis Center for Science, Mathematics, and Environmental Education, Columbus, Ohio.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE Sep 72
NOTE 130p.; Research Review Series 9
AVAILABLE FROM Ohio State University, Center for Science and Mathematics Education, 244 Arps Hall 43210 ($1.25)

EDRS PRICE MF-$0.65 HC-$6.58
DESCRIPTORS College Science; *Curriculum; Elementary School Science; Evaluation; *Instruction; *Learning; *Research Reviews (Publications); *Science Education; Secondary School Science; Teacher Education

ABSTRACT

A review of 402 documents at all school levels is presented to identify current trends in science education research studies. The documents are limited to journal articles, dissertation abstracts, and abstracted reports, primarily appearing in 1970. Nature of the research conducted is analyzed in terms of curriculum improvement projects, learning theories, child development, curriculum research, instrument design, teacher education, instructional methods, behavioral science, attitude analyses, student characteristics, and comparative and evaluative studies. Summaries are made concerning research findings from articles categorized in each of the areas. The authors indicate that individualization of instruction, Piaget studies, attitude measurement, inquiry teaching, and interaction analyses are emphasized. The quantity of research increased in 1970, with one-sixth of the studies related to new curriculum projects and over seventy percent presented as doctoral dissertations. The majority of the studies are short-term, localized, and of questionable value in the overall advancement of more effective science education. A bibliography of the reviewed articles is included. (CC)

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SCIENCE EDUCATION INFORMATION

REPORTS

RESEARCH REVIEW SERIES - SCIENCE

PAPER 9

A SUMMARY OF RESEARCH IN ELEMENTARY, SECONDARY, AND COLLEGE LEVELS OF SCIENCE EDUCATION FOR 1970

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September, 1972

SCIENCE AND MATHEMATICS EDUCATION INFORMATION REPORTS

The Science, Mathematics, and Environmental Education Information Reports are being developed to disseminate information concerning documents analyzed at the ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. The reports include four types of publications. Special Bibliographies are developed to announce availability of documents in selected interest areas. These bibliographies will list most significant documents that have been published in the interest area. Guides to Resource Literature for Science and Mathematics Teachers are bibliographies that identify references for the professional growth of teachers at all levels of science and mathematics teaching. Research Reviews are issued to analyze and synthesize research related to science and mathematics education over a period of several years. The Occasional Paper Series is designed to present research reviews and discussions related to specific educational topics.

The Science, Mathematics, and Environmental Education Information Reports will be announced in the SMEAC Newsletters as they become available.

RESEARCH REVIEWS - SCIENCE

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a one year period of time. These reviews are usually organized into three publications for each year according to school levels--elementary school science, secondary school science, and college science.

The publications are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Center for Science, Mathematics, and Environmental Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Your comments and suggestions for this series are invited.

Stanley L. Helgeson
and
Patricia E. Blosser
Editors

Sponsored by the Educational Resources Information Center of the United States Offices of Education and The Ohio State University.

This publication was prepared pursuant to a contract with the Office of Education, United States Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their judgement in professional and technical matters. Points of view or opinions do not, therefore, necessarily represent official Office of Education position or policy.

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A SUMMARY OF RESEARCH IN ELEMENTARY, SECONDARY, AND COLLEGE LEVELS OF SCIENCE EDUCATION FOR 1970

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INTRODUCTION

The review of research in science education for 1970 culminates the efforts of hundreds of individuals. It is heartening to note the increasing attention to science education research exemplified by the large output of reports for one calendar year. This productive effort represents the research activity of a wide variety of educators in the field including established researchers, dissertation writers, writers of project reports, and others.

A notable characteristic of nearly all of the research is its local nature. Very few studies have the scope one would desire for adequate generalizability to the large problems in science education. This has been a perennial problem of research in the field for decades. Little progress seems to have been made in overcoming the problem.

At the same time, new information is gradually accumulating in areas heretofore largely ignored, such as attitude development, individualized instruction, teaching of science processes, psychological studies, and the effects of the use of performance objectives. It is to be hoped that as additional pieces of the puzzle are brought to the foreground for scrutiny and evaluation, a more cohesive picture may emerge and a viable theory of instruction in science education may gradually evolve.

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* The authors of this report wish to acknowledge the dedicated assistance of their typist, Miss Judy Csizmadi, whose efforts in meeting the publishing deadline are sincerely appreciated.

PART I. NATURE OF THE RESEARCH CONDUCTED

In this report a total of 403 studies is reported. These consisted of articles found in various journals reporting research, dissertation abstracts, and abstracted reports of an unpublished nature such as papers presented at the annual meetings of NARST.

Because of the widespread interest in studies involving new curriculum projects, Table 1 shows the number of such studies at elementary, junior high, high school and college levels. Inspection of the table indicates that the BSCS program continues to attract considerable interest, with a total of 17 studies reported. The next area of interest was the Earth Science Curriculum Project at the junior high school level, followed by the Science Curriculum Improvement Study at the elementary level and by studies of the CHEM Study Program at the secondary level. A total of 67 studies dealt with some aspect of curriculum projects comprising approximately one-sixth of all of the studies reported, a sizeable fraction by any standard.

TABLE 1

STUDIES INVOLVING COURSE CONTENT IMPROVEMENT PROJECTS

Projects	Number of Studies
Elementary	
AAAS (SAPA)	4
COPES	1
ESS	3
SCIS	7
Secondary	
ESCP	8
IME	1
IPS	4
ISCS	4
SSSP (Time, Space and Matter)	2
QPS (Quantitative Physical Science)	2
BSCS	17
CBA	2
CHEM	6
HPP	2
Nuffield	1
PSSC	3
Total	67

Three tables (2, 3 and 4) are presented indicating the focus of research at the elementary, secondary and college levels. The particular categories selected were at the option of the authors of this report. An effort has been made to develop a parallel structure to the three levels although it is noted that each of the levels does not necessarily contain identical titles.

Review of Tables 2, 3, and 4 indicates a widespread breadth of topics covered in the research areas at all three levels. It appears that some of the newer areas of interest are those dealing with attitudes; individualized instruction; psychological studies, mostly Piagetian; teaching of science processes and studies having to do with behavioral objectives.

In the elementary group a total of 94 studies was reported with approximately one-third of those in the areas of learning theory and child development. All of the other categories had relatively equal numbers of studies with the exception of individualized instruction which had only three. Perhaps this indicates the newness of this area of interest. One would expect that the number of studies of individualized instruction would increase in subsequent years.

The research at the secondary level includes a total of 184 studies with the areas of methods of instruction, curriculum studies, and measurement and evaluation predominating. It is interesting to note, however, that a substantial number of studies of attitudes, 21, is reported, followed by an almost equal number of materials studies.

At the college level 46 of a total of 124 documents surveyed dealt with some facet of teacher education, and 36 were designated as comparative studies. The rest of the categories had approximately equal balance.

All of the studies reviewed have been reported in some form in this document. Those of particular interest which exemplified generalizable results, adequate methods of research, and clarity of the findings and conclusions have been selected for detailed treatment. Further information on studies not described in detail may be obtained by examination of the original study cited in the bibliography.

Part II of this report, Summary of Research Findings, gives relatively detailed information concerning the problem studied, the population used in the research, and the important findings or conclusions of the investigation.

TABLE 2

FOCUS OF RESEARCH (ELEMENTARY)

Categories	Number of Studies		Percent
Learning Theory and Child Development	34		36.2
Concept Formation		(17)	
Behavior Development		(11)	
Piagetian Studies		(6)	
Curriculum Studies	13		13.9
Evaluation Studies	10		10.6
Teacher Education and Teacher Traits	10		10.6
Measurement and Instrument Development	6		6.4
Individualized Instruction	3		3.2
Inquiry Teaching	7		7.4
Comparative Studies	11		11.7
Total	94		100.0

TABLE 3

FOCUS OF RESEARCH (SECONDARY)

Categories	Number of Studies	Percent
Concept Studies	8	4.4
Attitude Studies	21	11.4
Materials Studies	16	8.6
Methods of Instruction	29	15.7
Laboratory Practices	9	4.8
Curriculum Studies	24	13.1
Teacher Education and Teacher Traits	15	8.2
Measurement and Evaluation	33	18.0
Individualized Instruction	6	3.2
Processes in Science	4	2.1
Inquiry Teaching	7	3.9
Comparative Studies	12	6.5
Total	184	100.0

TABLE 4

FOCUS OF RESEARCH (COLLEGE)

Categories	Number of Studies		Percent
Teacher Education	46		37.0
Courses or Programs		(9)	
NSF Programs		(5)	
Attitudes		(5)	
Techniques		(10)	
Skills and Questioning Techniques		(5)	
Miscellaneous		(11)	
Curriculum Development	10		8.0
Developmental Studies	3		2.3
Evaluation Studies	6		4.7
Student and Teacher Characteristics	13		10.3
Students' Reactions to Science	3		2.3
High School Preparation and College Achievement	8		6.4
Comparative Studies	36		29.0
Laboratory Programs		(8)	
Methods of Teaching		(15)	
Programmed Instruction and CAI		(10)	
Behavioral Objectives		(3)	
Total	124		100.0

PART II. SUMMARY OF RESEARCH FINDINGS

ELEMENTARY SCHOOL LEVEL

Learning Theory and Child Development

In this section 34 studies are reported. They are divided into three categories: concept formation, behavior development, and Piagetian studies.

Learning Theory and Child Development: Concept Formation. In the area of concept formation, Stuck and Wyne (340) compared the effect of equilibration type training to the effects of SR reinforcement type training in developing weight conservation concepts in second and third grade pupils. Their purpose was to investigate the implications for instruction of the psychological concept of conservation by using it as a method of testing a fundamental science concept, that of weight. The findings showed that the SR group performed significantly better than the control group on the initial post-test for conservation of weight. No significant difference was found between the experimental groups on the measure of permanence of conservation beliefs. Significantly more transitionals than complete nonconservers of both mass and weight became conservers of weight during training.

In a study by Verizzo (364) concerning the conceptions of conservation and reversibility in children of very superior intelligence, the results showed that a substantial percentage of gifted children made abstract conceptions earlier than children in general. Where the concepts of conservation and displacement of volume had not been grasped students considered the words mass, weight, and volume as synonymous.

In another study of concept formation, Voelker (366) tested children in grades two to six in an effort to determine concept formation achievement. The problem consisted of two parts: 1) Can elementary school children learn the concepts of physical change and chemical change? 2) Does the amount of guidance children receive in formulating concepts have an effect on the success of their learning? The population consisted of two groups of ten children each in each of grades two, three, four, five, and six. The tasks required that the children correctly answer three questions: What is a physical change? What is a chemical change? How would you tell if a change were a physical change or a chemical change? The second task was to classify correctly a set of demonstrated and described phenomena as examples of physical changes or chemical changes. The third task was to support the correct classification of demonstrated and described phenomena with correct reasons. Based on the results of this study, it was concluded that an attempt to teach the concepts of chemical and physical change in this school using this methodology probably should not be attempted before grade six.

An additional study concerning concept development was done by Billeh and Pella (39) in an attempt to discern any cultural bias in the attainment of concepts of the biological cell by elementary school children. The problem was to compare the achievement of Jordanian and American children in grades three to six as indicated by scores on tests designed to measure knowledge, comprehension, and application of each of the selected concepts when both received comparable instruction related to the conceptual scheme, the biological cell. The authors reported that it is not possible to conclude that either of the populations, Jordanian or American, is superior by comparison in achievement on the concepts used in this study.

In a study by McClelland (211), a new approach to the introduction of concepts of energy at second grade level was developed through consideration of the nature of energy and of the capacities of children of that age. In this approach, the term energy is first associated with all physical changes. Specific changes are then used to introduce specific forms of energy. A sequence of five lessons in audio-tutorial format covering the selected energy concept was developed and trial tested among three second grade classes. The results showed that half of the interview group showed satisfactory generalizability of all the basic forms of energy. Ten percent showed a satisfactory concept of energy as an entity. None showed a completely satisfactory concept of energy conservation. Indications are that second grade pupils can attain valid concepts of energy through the medium of audio-tutorial materials, with special consideration for the capacities of children of that age.

Smith (316) investigated large group instructional techniques in teaching selected science concepts to elementary school children. Purposes included: 1) to determine the feasibility of teaching certain science concepts in elementary grades by large group science instruction, 2) to compare the large group teaching effectiveness of elementary school classroom teachers and a science specialist, and 3) to determine the relationship between success in learning the concepts and maturity as indicated by grade level, IQ, and sex. Twenty-eight concepts were selected from the conceptual scheme "The Particle Nature of Matter." The experimental population consisted of 498 pupils in grades one to six in a midwestern elementary school. Effectiveness of the classroom teachers compared most favorably with that of the specialist at the lower grades and for the simpler concepts and less favorably in the upper grades and for the more complex concepts.

In a related study by Green (126), the feasibility of teaching selected concepts relating to the particle nature of matter to students in grades two through six was investigated. The opinions of teachers and students regarding the feasibility of the lessons were ascertained by using questionnaires of a check list type, one for students and one for teachers, immediately following the teaching of each concept. Detailed analysis of the feasibility was made at each grade level. It was concluded that it is feasible to teach selected concepts related to the particle nature of matter to children in grades two through six.

Several additional studies relating to children's ability to form concepts in specific areas are reported. Smith (319) investigated children's concepts of heat. He first defined what is meant by a concept, and the distinction was made between the scientific concept and an individual's concept. A set of tasks covering a limited portion of the domain of the concept of heat was prepared with standard procedures for assigning the tasks in an interview situation. These tasks were then assigned to four groups of ten children in individual interviews. The assessments indicated that theoretical responses were very rare among first graders and the precausal responses were very rare among fifth graders. Relatively unexpected was a high frequency at both levels of mechanistic responses, those employing an unobserved nontheoretical process to account for a phenomenon.

Another study of concept development and communication abilities was done by Gillespie (117). The problem in this study utilized variations in leaf structure to study concept development and communication in young children. Children at all age levels exhibited great variance in abilities to verbalize concepts of leaf characteristics. Some children at all ages exhibited the ability to reason with unknown factors and to give rational explanations for natural phenomena. Children at all age levels tended to describe leaf structures in terms of familiar everyday phenomena. The study included several suggestions or implications for teaching, among which was that serious study of nature for children five years old or younger would likely be a waste of time.

A study by Riechard (281) investigated the acquisition of life science concepts by kindergarten children. An investigator-designed instrument entitled "Life Science Concept Acquisition Test" was used. The medium was 21 sets of colored pictures. As a set of pictures was presented to a subject, he was asked to respond non-verbally to a statement about the pictures by pointing to a specific picture or part of a picture. He was then asked to verbalize about his selection. The population sample involved 51 beginning kindergarten children. Among the findings were that significant differences existed among the scores made on the test by the subjects from three community settings. The mean score range from low to high was inner-urban, rural farm, and outerurban respectively. One finding of particular interest indicated that when predicting performance on the non-verbal measure from socio-cultural variables alone, the number of years of education of the subject's mother and the subject's community were the first and second most useful variables respectively.

Ryder (291) investigated elementary pupils' understanding of selected science concepts with the following two purposes: first, to determine whether specific experiences in the pupil's background significantly influenced the ability to understand two concepts on air pressure, and secondly, to investigate the effects of an advance organizer on the pupil's ability to understand the two concepts. It was hypothesized that previous exposure to certain relevant experiences would enhance the ability to master the concepts involved in the study, whereas a lack of exposure to these experiences would be disadvantageous to the learner. The sample consisted of 401 third and fifth graders of diverse experience backgrounds. Findings revealed that grade, sex, and treatment significantly affected pupil understanding of the two concepts, and that experience background had no statistically significant effect. It was concluded that 1) the advance organizer was most advantageous to pupils with rich experience backgrounds, and 2) the advance organizer approach was a potentially effective instructional tool for relating the content of advanced subject matter to elementary school children.

An additional study on the cognitive preferences of elementary school science students was done by Schmedemann (299). The study was designed to discover the influences of the Elementary Science Study program and of certain strategies on that facet of scientific attitude termed cognitive preference. Two investigator-designed experimental instruments were constructed. The findings showed that 1) there was no significant relationship between the cognitive preferences of students and the teaching strategies selected by their teachers, 2) there were no significant differences between the cognitive preferences of the students in the three groups of the study, and 3) there was no significant relationship between aptitude and the cognitive preferences of the students. The author suggested that questions should be raised concerning the effectiveness with which the objectives of the Elementary Science Study are being realized.

Tamppari (348) developed a model for determining biological attainment. The purposes of the study were 1) to specify biological concepts related to an important theme which is taught in existing biological curricula, 2) to order the identified concepts according to the learning theory of Robert Gagne', and 3) to study the attainment of the identified concepts by students in grades five, seven, and nine. It was concluded that it was possible to construct a model for biology curriculum development in accordance with psychological learning theory. The main recommendations were that biology curricula should be constructed according to a theoretical model based upon learning theory and validated by experts. Also, it was recommended that investigators who study concept attainment should precisely define the concept. A third recommendation was that in the early grades there should be more emphasis placed upon the teaching and learning of prerequisite subject matter and that the teaching and learning of concepts should be examined in the light of Piaget's theory.

In a study on subliminal perception and concept attainment, Taris (350) attempted to determine experimentally whether subject matter content can be taught subliminally to fourth grade pupils. The method consisted of flashing, through the use of a tachistoscope, certain science concepts during the show of a motion picture. The results indicated that it was unlikely that subliminal learning had occurred.

A study on bilingual science instruction was done by Ng (245) who investigated the effects of bilingual instruction as revealed in several aspects of science learning. Children were assigned randomly to monolingual and bilingual teaching methods. The following hypothesis was tested: Children taught bilingually will achieve better results than children taught monolingulaly on multiple choice tests for vocabulary, comprehension achievement, and conceptualization in science. On the basis of statistical evidence, the hypothesis was partially accepted. It was found that children taught bilingually surpassed children taught monolingually only in vocabulary and in conceptualization.

A study on concept development by Janke (159) was undertaken to determine the degree of agreement between science textbooks and scholars in earth science as to the earth science concepts to be included in the K-12 science curriculum. Analysis of the results showed that scholars from the earth science disciplines are in general agreement on earth science concepts to be included in grades K-12.

Summary. In general the concepts studies seemed to be lacking in a clear definition of "science concepts". Investigators in this area might be well-advised to consider tighter definitions and more precise descriptions of the problem being investigated. Findings concerning concept development appear to support the Piagetian hypothesis that maturation plays a major role in concept learning, perhaps outweighing any environmental or instructional influences superposed by the materials or by the instructional design.

Learning Theory and Child Development: Behavior Development. The second group of studies, dealing with behavior development, consists of eleven investigations. The first of these reported is by Raven (276). The purpose of his study was to determine if a set of sequentially articulated classification exercises could facilitate the classification abilities of second and third grade children. The population consisted of 210 second grade students and 175 third grade students. Third grade students achieved higher scores in classification tasks than second grade. Treatment groups achieved higher scores on classification tasks than the control group. Practice on the more complex classification rules enhanced the success on simple rules. However, practice on simple rules did not provide an advantage for succeeding on complex rules once practice on these rules was performed.

In a study by Susskind (341), a model of inquiry predicted that students would ask more questions and make more declarative statements when the teacher asked questions at a relatively low rate and used questions encouraging students to draw on their own experiences and contribute to a class discussion. The model was tested by oserving elementary teachers after they had participated in a seminar designed to change their questioning pattern to facilitate students initiation of discussion. A descriptive report of the data indicated that teachers asked questions rapidly and most were memory questions. Students rarely asked questions. Patterns of student responses in the classes of seminar participants tended to correlate as predicted with changes in the teachers' questioning techniques. The seminar produced small but significant changes.

Carter (60) studied the ability of primary school children to generalize behavioral competencies acquired in science to other content settings. Students in grades one to four who had used Science- A Process Approach were tested by individually administering the tasks of the science process instrument. Tasks to assess the level of the same skills in social studies, fine arts, and language arts were then administered. Data analysis revealed a similar ordering among students with respect to science and other subject areas. Students had similar levels of competency in each of the skills in each of the subject matter areas.

A study on behavioral development was done by Johnson (164) on the effects of the process approach upon IQ measures of disadvantaged children. His purpose was to determine the relationships of teaching process approach to increasing general intelligence. The population was a third grade class in a culturally disadvantaged area. Using a pre-test, post-test format with matched pairs, results showed that both groups increased their mean total IQ scores. The experimental group increased more than the control group by a significant amount. This study indicated that, through use of a process approach, disadvantaged children benefitted in the ability to think rationally.

Scott (305) in a study extending over a three-year period investigated the strategy of inquiry and styles of categorization. Two problems were studied: 1) Would an inquiry program have a continued effect on children's behavior after the novelty of the situation had passed? 2) Would the verbal behavioral changes in inquiry children in a three-year study be traceable to the elements of the elements of the strategy emphasized during this program? The results indicated 1) that instead of a leveling off as the Hawthorne Effect dwindled, the inquiry program seemed to have had a persistent effect on styles of categorization and 2) the inquiry strategy appeared to have had a continuing effect on the verbal behavior of this group of children over the three-year testing period. Several measurable changes were noted over the period. First, verbal fluency and flexibility were increased. Second, attention to detail became more acute. Third, inferences about invisible attributes showed a strong trend away from emotional and locational responses and toward inherent classificatory attributes. Fourth, each of these changes could be traced to a specific emphasis of the inquiry strategy used in this program. Thus it appeared that inquiry training could produce measurable behavior changes.

Also in this group of study, Allen (9) used a scalogram analysis of classificatory behavior. The Piaget hypothesis that cognitive skills are acquired in a fixed orderly sequence in which mastery at any level is dependent upon mastery of earlier more basic levels was tested. Allen concluded there was a general order of emergence; grouping skills were mastered first and class inclusion skills last. Also, it was suggested that before this hierarchy could be adequately tested the horizontal dimensions for each of the levels had to be handled carefully.

Rogers (287) attempted to determine the relationship between the teacher's perception of his pupils and classroom verbal behavior at the fifth grade level. The "Perception of Pupils Adjective Checklist" was used to measure the teacher's perception of pupils. The population was 34 inner-city fifth grade teachers and 38 outer-city fifth grade teachers in a large city. One hundred minutes of verbal interaction of each teacher were analyzed, using the Flander's Interaction Analysis System. The results of the study suggested that classroom verbal behavior during fifth grade science classes was significantly related to the teacher's perception of his pupils. The positive perceivers made greater use of pupils' ideas, criticized less, and made less use of their authority, had more verbal participation from their pupils, and exhibited more flexibility in their teaching. The negative perceivers made greater use of restrictive verbal behavior and used a greater number of routine questions, directions, and criticisms in combination with each other to control the pupils' actions. Having had a recent science methods course was not significantly related to verbal behavior and to the learning conditions that the teacher established during science lessons.

Another study involving verbal behavior patterns was reported by Moon (231). His study was designed to analyze selected examples of verbal behavior patterns in primary grade classrooms during science activities. The population of 32 elementary school teachers involved those who had received an in-depth study of the Science Curriculum Improvement Study teaching methods and materials. The findings suggested that those teachers who were exposed to the teaching methods of SCIS differed significantly from those employing conventional science teaching methods and materials, by demonstrating an increase in the amount of direct teacher influence displayed in verbal behavior patterns during science activities. A second finding was that there was a pronounced shift in the direction of much greater preferences for higher level questions displayed by the experimental teachers after the introduction of SCIS teaching methods and materials.

Nelson (242) studied the effects of post-laboratory discussion strategies on sixth grade children's learning of selected cognitive skills and principles. The problem investigated was, "When teaching science by inquiry to sixth grade children in an urban and suburban school, which of two post-laboratory discussion strategies was best for children's learning of selected science principles and the cognitive skills of observing, inferring, classifying, and verifying?" Approximately 200 students participated. The following conclusions resulted from this study: When teaching science in an inquiry fashion to sixth graders with the objective of increasing the quantity and quality of inferences, then the probing strategy was to be preferred to the non-probing strategy. When the objective was to increase the quantity of observations made, then the probing strategy was preferred in the suburban school while the non-probing strategy was preferred in the urban school. When the objective was to increase knowledge of science principles, then the non-probing strategy was to be preferred over the probing strategy.

A somewhat different study was done by Gray (125). A comparison was made of the effectiveness of two learning sequences in facilitating the acquisition and retention of certain mathematics and science behaviors. He concluded that the integrated learning sequence was generally superior to the non-integrated sequence in facilitating acquisition of the mathematical behaviors for the population defined in this study.

A study by Ogunyemi (256) was designed to simulate some aspects of classroom verbal interaction and to investigate their cognitive effects on students using cognitive theory as the theoretical rationale. Because the role of verbalization on learning has been found to be rather equivocal, he attempted to determine the effect that verbalized cues would have on the performance of subjects. The subjects consisted of 159 fourth graders who had two years of SCIS science. The results indicated that while subject determined verbalization of correct cues had no significant effect on the subject's performance, the effect of teacher supplied correct cues was significant for the female subjects but not for the males. It was inferred that when cognitive objectives constitute a main focus of classroom interaction, teachers should feel free to supply information to girls especially in individualized or quasi-individualized instructional settings prevalent in elementary and high school science classrooms.

Summary. It appears that at least as much research interest exists in behavior development as in concept development in the elementary school, perhaps as a result of increased emphasis on process goals and learning theories in recent years. It is difficult to generalize on the results of studies of this nature. However, when specific attention was given to behavioral outcomes in the instructional design, evidence of gains was accumulated. None of the reported studies dealt with matters of retention or achievement of long-range goals, a potential area for fruitful research in the immediate future.

Learning Theory and Child Development: Piagetian Studies. Interest in Piaget and in child development continues to absorb the energies of a large number of researchers in science education. The following five studies touch upon some aspect of Piagetian research. In a study by Wiegand (385), the maturational view of Piaget was compared with that of cumulative learning related to solving a science problem. If such problem solving is an outgrowth of the cumulative effects of learning of ordered sets of capabilities that build upon each other in a progressive fashion, then it should be possible to identify the subordinate capabilities involved in performing the complex task. The results indicated that intellectual development was brought about by the cumulative effects of the learning of concretely referenced intellectual skills rather than by the adaptation of structures of intellectual growth.

A study on intellectual development was done by Nous (254) to examine the various abilities subsumed under the process of correlational thinking. The results were consistent with the Piagetian notion that inversion and reciprocity are not combined into one operation at the concrete level but are above this atage. Fifth grade students were able to deal with intrapropositional presentations whereas older students were able to deal with the interpropositional aspects involved with the logical operations of equivalent and reciprocal exclusion. The data supported the notion that the ability to establish correlation was an ability specific to formal operation.

A third Piagetian study was done by White (384). One purpose was to design a task in which the change of appearance was the result of biological growth and development. The second purpose was to present the experimental tasks to a population and compare the ages and order of attainment of conservation using these materials with ages and order of attainment and using the classical plasticene ball materials. Both experimental and plasticene ball materials were presented to the same population. The first hypothesis that children attain conservation of mass before weight was not confirmed on either the plasticene ball or experimental materials. The number of conservers increased with age on all tasks. The second hypothesis that children would attain conservation of mass and weight with the biological material at a later age than with the physical plasticene material was supported by the data. It was suggested that the experimental tasks were of a higher level of complexity and might be outside the ordinary range of experiences of the subjects. The fact that a small number of subjects was able to conserve mass and weight on both Piagetian and investigators' tasks suggested that the latter materials could be used as a measure of children's ability to conserve conceptually at more complex levels.

Harding (131) investigated the organizer influence on children's responses to physical causality. The question to be answered was: "Are there significant differences to children's responses to Piagetian questions dealing with physical causality when children are interviewed by interrogators whom they perceive to occupy different roles in society?" The various interviews were placed in religious, non-religious, and by telephone categories. No significant differences were found among the groups. Analysis of the data indicated that the stages did not differ significantly from results found by Piaget.

In a study on Piagetian-type tasks for second grade children by Kamps (174), thirty-four subjects evenly split by sex were randomly selected from second grade classes in each of three cities, making a total of 102 subjects. Results showed that the subjects exposed to the AAAS science program received higher raw scores on measurement tasks than did subjects from other groups when compared with their scores on conservation tasks. The best overall performance was demonstrated by the group without unique mathematics or science experiences. This group was characterized by a higher degree of educational attainment by parents.

Summary. The field of Piagetian research is still relatively unexplored. Conservation studies seem to dominate the current scene. More subtle and complex ramifications of Piaget's basic theories remain open for investigation. Also, the implications for education at the elementary and junior high school levels have not yet become clear. More research is needed on the transitional zones between concrete operational and formal operational levels. Considering the normal wide variations among individual students in upper elementary and junior high school, well-controlled Piagetian-type research at ages 10-13 could add considerably to our understandings of learning at those levels.

Curriculum Studies

The first study reported in this category is that of Harty (135), who observed attitudes toward Science-A Process Approach of fourth and fifth grade teachers in ERIE pilot schools prior to an initial workshop session. In this study the attitudes of 54 fourth and fifth grade teachers from 21 pilot schools were studied prior to an initial summer workshop on Science-A Process Approach and prior to installation of the AAAS program during the 1969-70 school year. A questionnaire was mailed to each teacher. The data and conclusions were reported with regard to the following variables: AAAS curriculum characteristics, consultant functions and utilization, and student achievement. The results indicated that older, experienced teachers and those with graduate work were most familiar with Science-A Process Approach and were most favorably impressed by the program. Teachers with one to three years experience utilized manipulative equipment more regularly than other groups.

The second curriculum study, by Newport and McNeill (244), was a comparison of teacher-pupil verbal behaviors evoked by Science-A Process Approach and by textbooks. The investigators inferred that untrained teachers may misuse S-APA materials. There was an indication that training caused teachers to change their style of teaching or perhaps to select different lessons after training than before. There was also an indication that emphasis on science content was significantly less after training than before. Interaction analysis without instruction was relatively ineffectual. The interaction analysis system tells the teacher what he is doing but not what he should be doing. If processes of science are favored over content, the S-APA patterns appear more desirable. If content is favored over process, patterns of textbook usage by teachers appear more desirable.

There were several studies focussing on the SCIS elementary science program. Allen (8) evaluated certain cognitive aspects of the Material Objects Unit of the SCIS elementary science program. The purpose of his study was to investigate whether participation in the SCIS elementary science program at grade one resulted in performance superior to that of grade one non-participants in the program when certain SCIS objectives were considered. The medium used was the objectives of the Material Objects Unit. Conclusions from this study indicated that using a) the input variables of socio-economic status: reading, sex, and science program and b) the criterion measures in the objectives of the Material Objects Unit, that first grade SCIS children were superior to non-SCIS children only in their ability to serially order objects. A second conclusion was that SCIS children exhibited significantly more exploratory behavior than did non-SCIS children.

Altman (10) investigated interaction in inner-city and advantaged classes using the Science Curriculum Improvement Study. The population consisted of thirteen classes in grades three and four in inner-city and fifteen from similar levels in suburbia. Among the findings were: 1) advantaged students engaged in more than twice as much self-initiated talk as inner-city students, 2) advantaged classes as compared to inner-city classes were exposed to more verbal cognitive interaction and less procedural interaction, 3) both inner-city and advantaged teachers asked twice as many recall facts and relationship questions as observation, hypothesis, and test hypothesis questions, 4) in both inner-city and advantaged areas, lab work was a dominant part of the lesson, and 5) in a comparison of high achieving and low achieving classes within each socioeconomic area, high achieving classes showed a greater similarity to the SCIS recommended model.

Two studies are reported concerning teacher reactions involving Science Curriculum Improvement Studies. The first of these by Barnes (26) had as its purpose to ascertain teacher reaction to an SCIS training and implementation program. Thirty-three first and second grade teachers from four school districts participated in the study. In the findings: 1) the elementary teachers agreed on the relative merit of the workshop experiences of the SCIS in-service training program, 2) teachers' reactions to the workshop experiences were significantly different in August than were their reactions the following April, 3) the elementary teachers consistently rated the lectures on nature of science low in value as an aid in implementing the SCIS program, 4) the teachers' reactions to the workshop experiences appeared to be related to the teacher characteristics considered, and 5) the teachers considered as most valuable the workshop activities which required their active participation.

A second of the teacher reaction type studies was done by Baker (23) to answer the question: "What are the effects of science teaching materials on teachers' verbal behavior during elementary science instruction?" The subjects were 50 suburban sixth grade teachers and 14 middle and junior high school teachers. The results of the study support the following propositions: 1) teachers using ESS materials fostered greater student involvement and participation during science instruction, 2) teachers using ESS materials were more learner-centered in their teaching behavior during science instruction, 3) teachers using textbook materials restricted student involvement and participation during science instruction, and 4) teachers using textbook materials were more content oriented in their teaching behavior during science instruction.

Woodruff (397) assessed certain concepts held by selected children using the Conceptually Oriented Program in Elementary Science test of science concepts and individual interviews. In this study the COPES test of science concepts was administered to all children in grades four and six after the completion of a unit from the COPES materials. A semi-standardized interview schedule was used with selected pupils. Results indicated that the accuracy of the COPES test appeared to be limited by: non-science vocabulary, test format, procedural tasks, sentence length and complexity, words creating misleading mental sets, questions contradictory to response to a previous question, and inclusion of designated best choice statements fully consistent with the child's adequacy of concepts.

A study by Mechling (220) dealt with a strategy for stimulating the adoption and diffusion of science curriculum innovations among elementary school teachers. He investigated means by which innovations in elementary science teaching may be efficiently diffused to classroom teachers. Teachers were selected to adopt innovations and to extend the innovations within their schools. Findings indicated that neither adoption nor diffusion was facilitated by concentrating efforts on teachers identified as science opinion leaders. Dogmatism figures were significantly related to the adoption of innovations, with low dogmatic teachers showing greater changes.

Another study in this group was done by Lawlor (202) on the effects of verbal reward on the behavior of children in the primary grades at a dognitive task typical of the new elementary science curricula. The problem investigated was: "What are the effects of verbal rewards such as good, ok, that's right, fine, excellent, etc. upon the problem solving behaviors of pupils in a modern elementary school science program?" The subjects involved 202 second grade pupils in a middle class suburban school. The experimental tasks involved categorizing or sorting tasks which required the children to attend to the various physical properties of objects and to group them dicotomously on the basis of these properties. The tasks came from AAAS; Science-A Process Approach, First Grade; the SCIS Material Objects; the ESS Attributes Games and Blocks; and the ESS People Blocks. It was concluded that the use of verbal rewards which were not congruent with behavior resulted in less efficient problem solving than either a neutral no-reward situation or the use of rewards which were congruent with the problem solving behavior. The giving of rewards which were congruent improved the problem solving efficiency of girls but not of boys.

Heath (139) attempted to determine if there was a significant difference between a group of students being taught by a contemporary elementary science approach and another group of students being taught by a textbook oriented instructional methodology in the extent of achievement of selected reading skills and abilities. The reading skills studied included word recognition, critical reading, comprehension, and general reading level. Two samples consisting of approximately 120 fourth, fifth, and sixth grade students were compared. The students in sample one, contemporary programs, achieved the selected reading skills and abilities to a significantly greater extent than those in sample two, textbook oriented programs. The results of the study indicated that contemporary elementary science instructional programs promoted the development of science reading skills and abilities to a significantly greater extent than those programs which are textbook oriented. These findings and conclusions were in agreement with the stated aims of the newer elementary science programs and projects reported in the review of selected literature.

Summary. Studies of curriculum projects generally showed that children engaged in science learnings of the "new" projects were more actively involved, were able to ask more questions, understood science processes better, and did at least as well, sometimes better, on selected reading skills than those in more traditional types of science.

There was consistent evidence also that teachers can be successfully trained to use the new science curriculum materials effectively. It appears that training sessions with specific project materials were necessary to bring about the desired objectives. Teachers left to their own devices in using the new curriculums without suitable preparation and indoctrination had much less success and less positive attitudes toward the programs.

Evidence seems to be accumulating that elementary science teaching is changing through the impact of the varied curriculum projects in science of recent years.

Evaluation Studies

The following section consists of nine evaluation studies. Carey (58) attempted to determine the feasibility of utilizing separate taxonomic tests or a test consisting of a composite of different taxonomic items to evaluate instructional outcomes in elementary science. The procedure was to construct a test instrument with equal numbers of knowledge, comprehension, and application questions. Carey concluded that 1) the taxonomic type tests allowed the determination of the level of understanding at which pupils were achieving regardless of the pupil's level of performance of the total test and 2) levels of performance as indicated by earned total test scores were deceiving relative to the levels of understanding. For example, total test scores indicated a level of performance below that of chance when the pupils were able to recall the concepts. Also, total test scores indicated a high level of performance even though pupils were achieving only at the knowledge and comprehension levels of understanding and not at the application level.

Daugs (87) evaluated the influence of multi-level reading materials on the achievement of fifth grade elementary science pupils. The purpose of this study was to evaluate statistically the influence of student placement at a reading level by means of an informal reading inventory in one kind of elementary science materials. The results indicated that the informal reading inventory placed students lower on the materials used in this study than did the Metropolitan Reading Achievement Tests.

A third study of an evaluative nature was done by Deady (88) concerning the effects of an increased time allotment on student attitudes and achievement in science. The effects of increased time allotments and of teacher's preference for a particular time allotment on fourth grade student's attitude toward science were investigated. The sample involved 324 students from 16 classrooms. Teacher time preferences were determined from a questionnaire. During the school year all groups gained in science achievement. Changes in attitudes toward science occurred in both directions. No significant differences were found attributable to either time allotment or teacher preference for time allotment, and no significant interactions were found between student's reading level or IQ and time allotment.

Walbesser (370) studied the effect on test results of changes in task and response format required by altering the test administration from individual to a group form. Significant differences between the scores of individuals on the group and individual measures were observed. Students demonstrated higher competencies on the items employing the individual format. Changing the assessment task from an individual to a group format decreased the number of subjects able to complete the task on four integrated processes: controlling variables, defining operationally, formulating hypotheses and interpreting data. More students in the individual format succeeded on tasks associated with assessing behaviors such as naming in writing, identifying, and stating a rule in writing.

Schiele (296) developed and evaluated a model for teaching science in the elementary school. The model was designed for the six elementary grades and dealt with the organizational structure, curriculum content, and types of activities to be performed in the classroom. Three hundred eighty-four children were involved in the testing. Four implications were discerned upon conclusions of the study: 1) children indicated through their questions, actions, and statements that they readily identified the different operations they were performing; 2) the majority of children participating demonstrated a significant degree of understanding of the specific precepts and generalizations; and 3) children, whether slow or gifted, demonstrated that they could adapt the sequence of activities to their individual cognitive needs. In other words, learning was an individual process for them even in a group arrangement.

Anderson (13) investigated the efficacy of mutually aided learning in science to determine systematic and long term use of high school students in an instructional role in elementary school science classes. A group of five or six high school juniors or seniors served as learning assistants in an elementary school science class, with each high school student working closely with about five elementary students. The learning assistants taught 40 minutes per session and three sessions per week for 13 weeks. The basic design of the study included comparison of classes which had teams of learning assistants with classes involving only a regular teacher. Science units developed by the Elementary Science Study were used. The results of the study indicated that 1) the three major factors of school, teacher, and learning assistants influenced student outcomes, and 2) there was an interaction between the factors of school and learning assistants.

Bird (42) investigated teacher dogmatism and teacher behavior in science instruction at the elementary level. The Rokeach Dogmatism Scale Form E was administered to the forty-three teachers participating. The results suggested that this scale can be a useful predictor of teacher behaviors in elementary school science. Teacher dogmatism plays a part in teacher performance in the classroom. The open-minded teacher appeared less likely than the closed-minded teacher to exhibit behaviors which were inconsistent with the goal of providing students with the opportunity to learn through inquiry.

In a study of teacher attitudinal changes by Hovey (150), three questions were investigated. Could the projective tests of attitudes designed for fifth grade students be successfully modified for use with adults? Secondly, is there a relationship between the amount of experience a teacher has with a new science program, in this case SCIS, and his attitude toward the scientific process? And thirdly, is there a relationship between the type of training for using SCIS and teachers' attitude toward the scientific process? Eighty-eight kindergarten through sixth grade teachers were the subjects in this study. The following conclusions were obtained: 1) training to use a program prior to actual classroom use did seem to make a difference on attitudes, yet once the realities of the classroom were encountered there was indication that the training no longer made a noteworthy difference between groups, 2) subjects strongly considered experimenting to have a process orientation, and 3) both descriptive and statistical analysis indicated that the majority of subjects responded positively toward experimenting.

Summary. Evaluation studies were local and specific to the tasks at hand. For this reason it is difficult to generalize regarding the outcomes. One outcome seems worth highlighting; this showed superior performance by elementary children on tests using an individual format rather than a group format on items involving process skills. Perhaps the characteristics of skill learning by their nature lend themselves to more accurate evaluation in an individual mode than in a group mode.

Teacher Education and Teacher Traits

A study dealing with teacher education was reported by Wasik and Nicodemus (374) who investigated the effects of a workshop and use of specially developed science materials on fifth grade science classroom practices. They reported a study of science instructional activities in the classrooms of teachers who either had or had not participated in a workshop introducing new science materials. Ninety-one fifth grade teachers who participated in three science workshops during 1965 and 1966 constituted the sample. The method divided the teachers into three conditions: Condition A, no workshop experience and no materials; Condition B, consisted of workshop experience and the use of materials; Condition C, was workshop experience and no materials. This study showed a significant difference in classroom organization and classroom activities for all three conditions except for teacher activities with small groups. The authors concluded that materials were the focus of major change. Different instructional strategies learned in the workshop and utilized in the classroom did not persist when the materials were removed.

Jones (167) attempted to secure information on the effect of the lack of teaching experience on pre-service teachers' perception of relevance of education courses. An introductory experience was devised and the study examined the effects of experimental and controlled experiences on change in teacher behavior and concern level. Forty-nine beginning pre-service teachers were randomly assigned to the treatments. The results indicated that types of introductory experience made no difference in change on concern level and that the type of introductory experience made little difference in teacher behavior change. One out of thirteen behavior factors tested showed significant findings. The interaction analysis group became more flexible than did the Piaget-type interviewing group. It was concluded that flexibility may be the first behavior factor of those examined to be altered by interaction analysis training.

A study by Geer (116) was designed to analyze the effect of training pupils to provide feedback on specific objectives in elementary school science. One-hundred fifty students in grades four, five, and six were included in the study. They were divided into three treatment groups, one of which received training to provide immediate feedback to their teacher during instruction, one group to provide feedback by a written response handed to the teacher at the conclusion of each instructional session, and a third group received no feedback training and served as a control. One conclusion drawn from this study was that grade level may be a significant factor in the effect of feedback training on change in pupil achievement. Also, at the fifth grade level there was significant relationship between achievement gained and pupil attitude factors.

Johnson (165) studied teacher questioning behavior by investigating the problem: "Can questioning behavior of in-service elementary school classroom teachers be improved in the area of science instruction by using a specially designed model for question analyses in a non-directive program of self appraisal?" Five primary teachers participated in the research using video-taping and a specially designed questioning dissector grid. Among the findings, perhaps the most important was the fact that there was a substantial increase in the teacher participants' use of observational information processing and evaluative questions toward the end of the study. The five teachers tended to ask less memory recall questions as the study progressed.

In a study by Costa (82) an attempt was made to answer the following two questions: 1) Do teachers who are highly successful in learning to teach for inquiry have significantly different attitudes than those that are not so successful? 2) What are some of the effects of an inquiry in-service program on an entire school faculty with respect to attitudes, perception of teachers' behaviors, self-concept and classroom interaction? Approximately 120 teachers participated in various aspects of the study. The main conclusion was that to learn the behaviors of teaching for inquiry required certain identifiable attitudinal characteristics. Teachers who possess these characteristics seem more able to adopt the behaviors of teachers of inquiry than those who do not. Those members of the faculty group who demonstrated the greatest change in attitude, self-concept, perception and behavior also possessed attitudinal characteristics similar to those highly successful teachers of inquiry identified in the referent group.

In a study by Wallen (371), an analysis was made of the opinions of elementary science by two groups of teachers. Wallen investigated and analyzed the opinions of 280 teachers about teaching procedures, materials, content, and time for elementary school science. One group of teachers included those who had received instruction in the inquiry approach (SCIS methods) and the second group included those who had training to teach from a textbook only. Among the conclusions were: 1) the inquiry types of methods courses were better oriented toward educating teachers in obtaining a wholesome attitude toward science teaching and increasing the teacher's interest in science, and 2) the inquiry centered teachers, a) have had education which has guided them in the selection of science content directed towards the achievement of elementary science objectives, b) were better equipped with physical and library facilities which enhanced the elementary science program, c) have a program which was both process and subject matter whereas the textbook centered teachers' program was subject matter centered only, d) spent more time on science, e) provided opportunities for five essential learning experiences: observation, measurement, experimentation, data interpretation, and prediction, and f) were better qualified to cope with the problems involved in classroom management and the necessary aids to classroom procedures for teaching elementary school science.

D. F. Smith (318), investigated the relationship of teacher sex to fifth grade boys' sex role preference. This study was stimulated by the belief that our elementary schools have been overly feminized for the past half century and that a realization of the potential damage of this state of affairs, particularly with respect to boys, has led to an increased demand for a greater number of male teachers in the elementary school. The primary purpose of this investigation was to determine the effect of the male teacher on the male pupil. This study involved a sample of 20 male and 21 female fifth grade teachers and their students. Teachers were matched as to age, marital status, teaching experience, educational preparation, and contrasting psychological and biological sex. The results showed that 1) introducing a male teacher into the classroom was conducive to reducing the degree of psychological feminacy of boys, 2) the male teacher had a positive effect on the development of a positive school related self-concept of boys, and 3) while male teachers seemed to have a positive effect on the achievement of boys on mathematical problem solving, no such effect appeared with respect to computation or science.

G. F. Smith (320) investigated the effects on student achievement in elementary science programs resulting from in-service training and the use of additional instructional aids. In this study 24 teachers from a school system not using the new elementary science programs taught representative new units to over 500 students. These were variations in in-service training and in the amount of classroom science equipment provided. For each unit, the teachers selected for training received a teacher's guide and specific training for the unit. The teachers not selected for training received only a teacher's guide. Some classrooms received sufficient laboratory instructional aids to allow students to work in small groups of two to four students. Others received minimal equipment so that their lessons included demonstrations rather than maximal interaction of children with materials. The findings showed that additional equipment resulted in significantly greater achievement only at the first grade level, but that all pupils expressed a preference for additional aids. Specific teacher training for the unit did not produce significant differences in pupil achievement.

Summary. Several studies of teacher traits and education focused on characteristics indicative of inquiry teaching. It appeared that kind and availability of materials played a major role in development of the requisite inquiry teaching behaviors. As noted with the curriculum studies, teachers who received specific training through materials, audio-visual techniques, and in-service programs showed significant behavior changes tending toward inquiry teaching methods. One might conclude that energy spent in facilitating behavioral changes in teaching science pays dividends in proportion to its direct application to specific courses and tasks.

Measurement and Instrument Development

In this category, four studies dealt with the task of developing instruments for special research problems. The first of these, by Doran (96), concerned the development of test items related to selected concepts related to "The Particle Nature of Matter." The purpose of the study was to develop test items related to the conceptual scheme that were valid, reliable, and usable with pupils at grade levels two through six. Criteria were set up for establishment of item validity and usability of the items was judged on the basis of scoring, administration, and minimal reading demands upon the students. Two items in the test satisfied all eight of the criteria and 104 of them met six or more of the criteria.

Kernaghan (181) developed and analyzed a pictorial physics test for grades five and six. One-hundred items in six physics areas were developed for grades one through six. Through the use of pictorial questions in a multiple choice format, 850 students were asked to choose the one that was true in relation to the stem. The wide distribution of scores for both tests indicated the measurement of a wide range of abilities with respect to the subject's basic understanding of physics. Several other conclusions led to the general consensus that pictorial tests can be used successfully with grades five and six to measure physics principles.

Farrell (106) attempted to construct an audio-visual instrument as a means of identifying elementary school teachers who were superior in evaluating science instruction. Use was made of a slide series of 120 kodachrome slides depicting good and poor science learning. Findings showed that teachers rated by their principal as successful science teachers may not necessarily recognize quality science teaching. This implied that personal ability was not the only factor necessary for recognizing such teaching.

A study attempting to show the relationship between mathematical skills and scientific processes in the sixth grade was done by Beltran (32). Major purposes of the study were 1) to identify and analyze basic scientific processes and mathematical skills germane to process teaching of science in the sixth grade and 2) to design and construct two types of process oriented science exercises. A sample of 175 sixth graders was used in this study. Results indicated that the potential of

Correlative process teaching of science and mathematics in the sixth grade which makes use of the structured type of science exercise should be explored and the suggestion is made that further explanation of the efficacy of correlative process of teaching of science and mathematics be made.

Summary. Studies of measurement and instrument development were severely limited at the elementary level. Limited information was given on validity and reliability. Usability beyond the specific tasks for which the instruments were designed is extremely improbable.

Individualized Instruction

Reflecting the rise of interest and increased usage of individualized instruction methods in the elementary school, three studies are reported. The first of these by Yarrison (398) was an exploratory study of the use of a method of individualizing instruction in the teaching of science to sixth grade pupils. A purpose of the study was to obtain data on whether there were differences between children taught by individualized instruction and children taught as a whole group in certain aspects including attitudes, interest, pupil judgement of teacher behavior, problem solving skill, and understanding of science concepts. Two groups of sixth grade pupils totaling 75 children were used in the study. The groups were similar in mental ability, chronological age, and proportion of boys and girls. Among the findings were that the pupils in the individualized group were able to learn science concepts and skills and carry out activities independently. Most of the pupils stated that they preferred individualized instruction to group instruction. It was recommended that further research be done of a similar type comparing individualized instruction and group instruction.

Gain scores in science of students who used individualized science materials and those who used traditional textbook materials were compared in a study by Charles (68). The main purpose of the study was to determine if cloze tests were sensitive to gain measurement when an individualized approach and a traditional textbook approach to science instruction were used. A sample of 300 children equally divided among boys and girls was used. The instructional program covered three weeks. Several conclusions were drawn: 1) cloze test instruments were sensitive to gain measurement, 2) the individualized approach to science instruction was not superior to the traditional science textbook approach in terms of cloze test gain scores for the three week period, and 3) cloze test results were valid measures of reading comprehension ability.

Neujahr (243) analyzed teacher-pupil interactions when instruction was individualized. A class of sixth grade pupils was video-taped for a week in mathematics, social studies, and science. Each of the three teachers worked primarily with individuals or small groups. Among the findings were that teachers and pupils have far different roles in the two methods of teaching: individualized and traditional. In the individualized mode, pupils make far more initiatory moves. In this study, they did 50 percent of the structuring and 24 percent of the soliciting. The teacher did over 50 percent more responding. When analyzed separately for boys and girls, it was found that the average girl made 70 percent more moves than the average boy. The girl talked more with the teacher because she initiated a higher percentage of interchanges with the teacher than did the average boy. It appeared that boys and girls play the game of individualized learning in different ways.

Summary. Three studies do not provide an adequate basis for rigorous generalizations, however, it does appear that some tentative conclusions may be drawn. While the evidence does not suggest that indivisualized instruction is superior to more traditional approaches in promoting student achievement, it does indicate that with individualization students do learn science concepts and skills, that they can carry out activities independently, that they make far more initiatory moves, and that they prefer this method of instruction. In view of the fact that these results are all consistent with the recognition of individual differences in learners, it seems that further research on the utilization of individualized instruction would enable us to move beyond the lip-service stage to the effective implementation of an important educational principle.

Inquiry Teaching

A group of studies is now reported concerning inquiry teaching in the elementary school. The first of these by Galey (112) related to the lack of preparation of elementary school teachers to use the new elementary science curricula which employ inquiry. The null hypothesis of no significant difference in abilities of two groups of first grade children to classify objects after one group is taught by inquiry techniques in television lessons and the second by the same techniques in classroom lessons was not rejected. Inquiry teaching techniques were as effective in television lessons as in classroom lessons in helping first grade children develop and use the skills of classification. Another conclusion showed that students could be motivated by television lessons to continue experimenting of their own volition after the close of the program.

Schlenker (297) attempted to determine whether a physical science inquiry development program achieved significantly different results than a traditionally taught program using similar science content when taught to elementary school pupils in grades five through eight. The sample consisted of 582 pupils in fourteen classes. Among the conclusions were the following: 1) children who studied under the inquiry development program achieved significantly greater fluency and productivity in using the skills of inquiry or critical thinking. The other two conclusions indicated no significant differences in the mastery of content or in the retention of knowledge between the two methods of study.

Schmiess (300) attempted to determine whether sixth grade students could successfully engage in scientific investigation. The success of the students' investigation was measured by their proficiency in solving selected problems, interest in science, and growth in solving new problems. Results showed that the question whether sixth grade students had the ability for scientific investigation could not be answered statistically. No significant differences were obtained between high, average, and low achievers on interest. There was no significant difference between boys and girls on solving selected scientific problems, interest, and ability to solve new problems.

In a study by Rains (273), again comparing inquiry centered and traditional science in elementary schools, the results indicated a significant difference in teacher-pupil interaction in the two methods of presenting science in the elementary school. The traditional science teacher had significantly more teacher-pupil verbal interaction than did the teacher using an inquiry-centered learning approach. It was found that boy-girl interaction was significantly higher in the inquiry centered learning science than in the traditional science method.

In a study by Abraham (1) the effects of post-laboratory discussions in science on selected inquiry skills were investigated. Children in four sixth grade classes from an inner-city and suburban school were selected for the study. The effects of two different post-laboratory discussions were investigated with respect to four specific inquiry skills: observation, inference, verification, and classification. Results indicated that 1) the instructional program had increased the skill of observation, but both discussion techniques were equally effective, 2) divergent discussion was significantly more effective for developing the skill of formulating inferences from observation, and 3) neither discussion technique was more effective for developing the skills of verification and classification.

Boyd (48) attempted to demonstrate that conceptual categorization behavior of deaf children could be altered by specific experiences in the manipulation of objects. The Goldstein-Sheerer Object Sorting Test was used for the measurement of conceptual categorization behavior. The results supported the rejection of the null hypothesis that participation in specific inquiry would cause no significant change in the abstract categorization behavior of deaf children. This conclusion was justified in that the conceptual categorization behavior of deaf children was altered by specific experiential enrichment.

Summary. A feature of the inquiry studies worth noting is the absence of definitions of inquiry teaching. Broad characteristics of teacher-pupil interaction, questioning, and practice of science process skills seemed to characterize the type of teaching called "inquiry" but tight definitions were absent. One would hope that future studies of inquiry teaching would begin to clear up the prevalent confusion by defining the problem and terms carefully.

Comparative Studies

Following is a group of comparative studies in elementary science. The first of these by Thornton (355) compared the effectiveness of programmed instruction, educational television and traditional teaching. In this study a 35 item multiple choice test was used before and after instruction of 452 grade six students in a unit introducing human biology. The material was taught by six linear programmed lessons, six 20 minute television lessons, traditional classroom methods or a combination of these. The results showed that traditional classroom teaching produced significantly higher student achievement than educational television or programmed instruction used alone or in combination and no significant difference in achievement when compared to a combination of all three methods. Educational television and programmed instruction used alone or in combination produced no greater achievement than no science instruction. Information about the kind of test, whether it was factual, problem solving, reasoning oriented, or some other emphasis, was unavailable.

In another study, Gallagher (113) compared the effects of instruction presented in the individual audio-tutorial mode and the teacher directed group mode. Three hypotheses were formulated. The first was that pupils instructed individually in the audio-tutorial mode would be distracted from their tasks less than pupils who were instructed as a group. The second hypothesis was that pupils who were individually instructed would demonstrate greater achievement on the post-test than pupils who received group instruction. Hypothesis three stated that pupils who received their initial sensory input lesson individually and had subsequent instruction in a teacher-directed group would demonstrate greater achievement on the post-test than pupils who received instruction in only one mode. The findings indicated that hypotheses one and three were not rejected. However, hypothesis two was rejected in this study. Curriculum developers and teachers may conclude that instructional tasks should be assigned to various instructional modes depending upon the outcomes sought.

A study was done by Jourdane (171) to determine if children who attended a bilingual math-science center would increase their level of performance on a test of problem solving and scientific thinking to a greater degree than would their counterparts. Eighty-six sixth grade students in an elementary school were tested with the Sequential Test of Educational Progress, Science 4B, developed by ETS. The results showed that the experimental group which attended the center improved considerably more than did the control group. The author concluded that a math-science center should be a basic part of every bilingual school.

Wise (392) studied outdoor versus indoor learning in elementary school science. The problems investigated were: 1) Do students acquire more science knowledge, more comprehension, and have greater retention when taught by the direct experience approach than when taught by outdoor or indoor classroom approaches? 2) Do more students make observations of the outdoor environment when taught by the direct experience than when taught by the other two approaches? Three fifth grade classrooms, with a total of 261 students, were used in this study. Results showed that significantly more students in the direct experience group had made outdoor observations in relation to the science content studied.

Pagano (259) did a comparison of the effects of four teaching strategies on the acquisition, retention, and transfer of selected science concepts in the sixth grade. Results showed that teaching strategies in which concept verbalization took place in the form of student summary statements or in which the concept was not verbalized, had a significant advantage over other treatments, both with respect to immediate recall and retention. Also, teacher verbalization of a concept was essentially ineffective in producing significantly higher mean scores on measures of concept acquisition, retention, and transfer.

Luong (209) attempted to determine the relative effectiveness of two methods, discovery versus reception, in teaching the principle of work. The subjects were 80 fifth graders and 80 eighth graders. He found that at the eighth grade level the reception approach yielded better results in both tests than the discovery approach. At the fifth grade level, no statistically significant difference was detected but results also showed that in both tests eighth graders obtained a significantly higher score than that achieved by fifth graders.

Marshall (218) investigated three methods of science instruction using fifth level students in a non-graded elementary school. The purpose of the study was to compare the effectiveness of three methods of instruction on science concept achievement, attitude toward science, and time needed to complete the unit of study. The three methods were self-directed independent study, self-directed group study, and a combination of self-directed independent and group study. Fifty-two children in the fifth level served as the population sample. Results were mixed, but generally all groups showed gain regardless of the method used in science concept achievement. All groups showed positive changes in attitudes toward science regardless of the method used. The mean response of all groups in attitude toward method of instruction was identical in the positive direction.

A study by Hastings (138) concerned relationships between teacher-pupil verbal interaction and pupil achievement in elementary school science. Findings showed that indirect teachers exhibited more acceptance of pupils' ideas and asked more questions of their pupils than did direct teachers. Direct teachers on the other hand, gave more directions and more criticism than did their colleagues. Indirect teachers' classes did not differ significantly in achievement from classes taught by direct teachers. Regardless of the teacher's behavioral style, girls made greater achievement gains than boys.

Summary. The comparative studies dealt with local and specific matters of concern. Rather than attempt to summarize this diverse group, the reader is directed to the individual studies for information on the specific problems or methods under comparison.

SECONDARY LEVEL

Concept Studies

An interesting pioneer study by Morris (236) utilized word association techniques in the investigation of changes of verbal behavior of seventh grade pupils in the ISCS program. This was an attempt to provide information of use to curriculum writers in selecting, sequencing, and repeating essential verbal interaction among the concept words in order to facilitate the acquisition of those concepts by pupils. This study represents a preliminary effort in the development of a lesson writing paradigm. Morris concluded that word association techniques used in this study could provide information of immediate use to curriculum writers during the formative evaluation stages of material development.

Cunningham (84), compared concept attainments in modern and traditional high school physics courses. Four-hundred eighty-four students participated in the study. A test was designed to measure students' abilities to use their knowledge of the concept "refraction" in the solution of problems. Comparisons showed that the modern physics group acquired a significantly greater amount of knowledge of the concept than did the traditional physics group. In general, the results of this study supported the claim that the modern physics course, as opposed to the traditional physics course, tended to emphasize the development of concepts.

Coleman (77) investigated the achievement in science of ninth grade students enrolled in two different integrated science courses. The first of these was the Earth Science Curriculum Project (ESCP), and the second was a commercial, integrated ninth grade earth science course. The main objective was to determine which of these integrated science courses was more effective in terms of student achievement in the development of interdisciplinary science concepts. Three-hundred subjects were used for a period of nine months in this study. Results showed that the ESCP course was the more effective in student development of interdisciplinary science concepts.

Baker (22) investigated the role of teaching models in science concept learning in secondary school biology. He explored the relative effectiveness of two methods of teaching molecular biology to a group of tenth grade students. The experimental group used a lecture-demonstration type presentation with three dimensional models. The control group was taught identical content using only a lecture approach. Results showed that the experimental treatment involving the use of two and three dimensional models of the DNA molecule made a significant difference in subject matter achievement among those students in the model group.

Summary. Based on the four studies cited, concept development appears to be fostered by the use of materials from curriculum improvement projects and by manipulative activities.

Attitude Studies

This section includes three subsections: 1) the development of instruments, 2) attitudes toward subject matter, and 3) miscellaneous effects of attitudes. The first subsection contains three studies.

The first was done by Bauman (28). His main effort was to investigate the relationships of science interest data using three instrumental formats. The three formats were the scaled rating, the block, and the card sort. In the block format, factors were identified by the headings or concepts. In the scaled rating factors were identified by descriptor adjectives or scales, while in the card sort format, factors were identified by both adjectives and concepts. The sample was 600 high school students from 37 classrooms. His major conclusion was that format made a significant difference in the factor structure.

Champlin (64) developed and field tested an instrument designed to assess student beliefs about the attitudes toward science and scientists. His results indicated that student attitudes were positively correlated with school setting, grade level, and sex, while there was a negative correlation between student attitudes and belief scores. He concluded that an accurate understanding of science and scientists was not prerequisite to having a favorable attitude toward science and scientists. He also concluded that student aptitude was a primary factor in association with belief and attitude scores while school setting was of secondary importance.

Moore (234) made an effort to develop, field test, and validate a scientific attitude inventory. The inventory consisted of twelve basic attitudes broken down into four subsets: 1) positive intellectual, 2) negative intellectual, 3) positive emotional, and 4) negative emotional. Three items were statistically controlled, namely the pre-test score, the IQ, and the science grade point average. He found that the treatments given to the experimental groups were more effective in producing positive change in the assessed attitudes than was the treatment given the control group. Detailed explanations of the treatments are found in the report. Analysis of the data indicated the inventory was appropriate with biology as well as with physical science classes.

The second subsection of the study of attitudes deals with attitude toward subject topics. Glass (119) did a study which involved a development of an instrument to determine the teacher's and student's educational objectives in the affective domain for high school biology. Based on the responses of the scale, a profile of educational objectives in the affective domain was developed. Glass used a statistical technique to match the profile of each of his students to the profile of each teacher. He suggested that the instrument may be used to study transfer of the objective in the affective domain from teachers to students.

Krahm (192) investigated attitudes and opinions of principals and teachers involved in an experimental earth science program. Forty-four principals and sixty-three teachers, representing 55 percent of the original sample, returned the questionnaire. The findings were: 1) the principals were more open than were the teachers according to their responses on a dogmatism scale and had higher commitment scores as measured by the science support scale; 2) the principals' perceived belief systems were related positively to their appraisal of the nature of the program, student learning, and teachers' qualifications; and 3) the principals' perceived level of science commitment was related to their appraisal of student learning while the teachers' perceived level of science commitment was related positively to their evaluation of the nature of the experimental program.

In a study of the attitudes of high school students toward air pollution, Swan (343) developed and tested an instrument to assess attitudes and coping responses to air pollution and to gain insight into the factors influencing these attributes. The population consisted of 173 senior high school boys. Their concern for air pollution was measured by two instruments: a forced-choice questionnaire which paired air pollution control with twelve other problem solving programs for cities, and two stories describing a specific air pollution aituation, asking the subject how much time he would be willing to spend working on solving the problem. Scores indicated air pollution was viewed as a relatively serious problem.

In an effort to study the attitudes of high school chemistry students toward biology, Weinstock and Watters (377) compared attitudes of 65 students towards biology and chemistry. They also related such things as chemistry grades, differential aptitude test scores, and grade point average. They found several significant differences in attitudes of students toward the two subjects in areas of encouragement to do research, modernity of the courses, value of lectures, and value for college preparation.

Troyer (359) investigated the influence of teachers' and students' educational set and the teachers' flexibility on student achievement in biology (BSCS Yellow Version). He found that conceptual students achieved significantly higher than factual students and that student achievement was significantly higher under a conceptual teacher. There was also a significant positive correlation between teachers' scores on the Educational Set Scale and the Philosophic-Mindedness Scale.

Amos (11) surveyed the opinions of biology teachers about the importance of the scientific method and related it to the General Certificate of Education examination provided in England. The results indicated that the teachers saw a need to include the scientific method in their teaching, but the General Certificate of Education presented the students with facts and not the scientific method.

Simpson (313) studied the effect of teacher science support as measured by the Science Support Scale to gain normative data on the instrument for use with high school students. He used 24 tenth grade biology teachers in a large system and also obtained data from 618 students. In the first phase he found a negative relationship between the Science Support Scale value of teachers and that of the students. In further study he found that students had difficulty understanding several items of the scale, items such as homosexuals, sex deviants, religion, God, Godlessness, and women. He concluded that the Science Support Scale was not an appropriate instrument for measuring science support among high school students.

Fiegel (107) attempted to determine the elements which influence the selection of high school chemistry. He surveyed 300 tenth grade biology students, 51 counselors and 43 chemistry teachers. The rank order for the first eight criteria deemed important for tenth grade students to consider prior to making their decision regarding the selection of chemistry were: ability, vocational goals, interest, science grades, college plans, math preparation, student drive and scholastic average. Fiegel concluded that tenth grade biology students, high school counselors and high school chemistry teachers thought along similar decision making lines when considering the selection of high school chemistry.

Waltz (372) studied the chemistry laboratory behaviors which affect scientific understanding and attitude development. The study was designed to delineate a list of behavioral practices and to determine which contributed most to the two areas cited above. These were measured on the basis of the Test On Understanding Science (TOUS) and the Vitrogan Attitude Scale (VAS). The results of the study indicated that 1) none of the 18 behavioral practices investigated contributed to a better attitude toward science as measured by VAS, 2) only one of the behavioral objectives, namely the practicing of the behavior of relating principles from one subject area to another, was significant, and 3) none of the 18 behavioral practices as measured by TOUS indicated a contribution to a better understanding of the methods and aims of science.

Hecht (140) studied student attitudes in the Introductory Physical Science course (IPS). This study involved 480 students. A random sample of 60 traditional physical science and 60 non-science students comprised a statistical group comparison designed to test attitudinal outcomes of a traditional course. The groups had equivalent IQ scores, math scores, reading scores, and ages and had equivalent scores for 17 of the 18 attitude factors on the pre-test. The conclusions of the study indicated 1) there were no significant differences in the attitude towards six concepts of the semantic differential instrument by IPS students over the period of a school year, 2) there was significant difference demonstrated in the attitude towards the six concepts by IPS students over a calendar year, and 3) there was no significant difference between the attitudes of IPS and non-science students.

Milson (228) developed and evaluated physical science materials designed to improve the attitudes of the secondary school slow learner. He found that the presence of physical science instructional materials caused a significant improvement in attitude toward science and toward the science laboratory.

Kendall (180) used selected high school physics students to study the scientific behaviors promoting an understanding of science and a positive attitude toward science. He used a list of 19 overt behaviors and found one that correlated with their understanding of science and five that correlated with the students' attitude toward science.

Korth (190) attempted to assess students' understandings of the relationship between science, technology, and society. The responses of science oriented and non-science oriented high school students were compared. In this study science oriented students showed a more positive attitude toward science, a better understanding of the nature of the scientific enterprise, and a more realistic conception of the characteristics of scientists. Non-science oriented students were weakest in areas related to the nature of science and the characteristics of scientists.

Hug (151) studied attitudes of students toward independent study. He chose 436 high school biology students and divided them into four groups, three experimental and one control. The three experimental groups involved small group lecture, large group lecture, and independent study. He found that there was no significant difference on achievement, but a questionnaire administered at the close indicated a substantially higher positive attitude toward experiments by students in the independent study section.

The remaining two studies deal with the climate of the classroom. The first one by Ackerson (2) deals with the relationship between organizational climate and the biology student's perception of biology practices. The organization theory of the authenticity of interactions between the principal and the biology teacher and between the faculty and the biology teacher was the focal point of this study. Findings showed 1) there was no relationship between authenticity and the biology curriculum practices present within the school, 2) males perceived the biology practices differently than did females, 3) the biology teacher's perception of the esprit of the school correlated significantly with the biology laboratory practices, and 4) the biology teachers viewed the climate of the school as being more open than did the other faculty members.

Clark (74) determined whether the so-called two cultures gap between the humanities and the sciences, as publicized by Snow, existed in the high school, and if so, how wide was it and what was its nature? Investigation involved the teachers of the humanities and the teachers of the sciences in the schools. The results indicated no discernible culture gap in the high school. There was some evidence that the two groups had differing attitudes towards the function and importance of science teaching in the schools. Data revealed no significant difference between the two groups and their personal attitudes towards each other. There was some evidence that teachers in both groups felt that science was a more prestigious subject today than the humanities. The results indicated that each group had a greater knowledge of the key names and terms from its own culture than from another culture. There was no evidence that science teachers knew more of the humanist culture than did the humanities teachers of the scientific culture.

Summary. Attitude studies are important current topics of consideration. At this point there are still few studies which involve the development of measuring devices. Attitudes are often used to study other phases of education. In the future it is necessary to study the effects of attitudes on the other issues and topics, and to develop more precise measuring instruments.

Materials Studies

In this section thirteen studies which deal with multi-media, audio-tutorial, and programmed instruction are considered. Castelli (62) investigated the effect of single topic inquiry films in BSCS biology upon critical thinking ability and process skills. His study consisted of a four group design and used the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. Results indicated that critical thinking ability could be improved using an inquiry method of instruction in biology. The process skills appeared unaffected by the use of the inquiry films.

Volker (367) made an effort to compare a multimedia system for teaching high school biology with a conventional approach. Twelve sections of students taking high school biology were divided into six sections each of experimental and control. The control group was taught by the lecture-demonstration laboratory method. The experimental groups were taught through a programmed audio-tutorial type technique. The major conclusion of this study was that the multi-media system for teaching high school biology could be superior to a traditional method in causing gains in achievement and attitude. The personality factor measured showed little relationship to the type of instruction.

Woodman (396) studied the influence of Physical Science Study Committee (PSSC) films on certain learning outcomes. He recommended that teachers select films on criteria other than achievement or understanding of science. These might include choosing films to stimulate interest, to break up class monotony, to supplement laboratory work, or to increase the range and scope of the course.

Gates (115), using 100 poor readers, analyzed the effectiveness of audio tapes when used as a supplement to the Intermediate Science Curriculum Study. Among the findings were that students in the experimental group 1) had a significantly greater preference for science as measured by the Prouse Subject Preference Test, 2) achieved course principles and concepts to a significantly greater level as measured by the printed ISCS final examination, 3) had a significantly greater science vocabulary reading grade level and a greater overall reading vocabulary as measured by the California Reading Test.

Waine (369) compared the effectiveness of a programmed text with more customary instructional methods in teaching chemistry topics to biology students. He also investigated if such instruction had an effect on the final achievement in biology. This study included 326 students in 14 biology classes and employed three chemistry teaching techniques: 1) programmed text, 2) customary classroom instruction, and 3) no classroom instruction. Findings indicated that the programmed instruction was superior to other methods in achieving chemistry knowledge. They also indicated that the knowledge of fundamental chemistry did not appear to improve biology achievement. In another phase of the study he determined that taking time from biology instruction to teach chemistry fundamentals did not detract from achievement in biology.

A study by Adelman (3) involved a structured approach to teaching a science principle using a programmed instruction film. He used this approach in grades 7-9 and concluded that a programmed film was an effective technique for teaching the principle of a pendulum. He also concluded that giving the rule may be useful for eighth or ninth grade subjects but giving the rule to seventh grade subjects is detrimental for learning. He also found that it is necessary to include instruction that allows for the exclusion of irrelevant variables.

Stedman (332) studied the effects of prior knowledge of behavioral objectives on cognitive learning outcomes when using programmed materials. The population was a high school genetics class of 144 students. He concluded that varying the form of behavioral objectives did not significantly affect the achievement, but mental ability and motivation both significantly affected achievement.

Marshall (217) completed a study involving the writing and use of a programmed text covering selected subjects in general biology. She found that the experimental group showed no significant difference over the control group in gain scores, mid-term examination scores, or on the final examination. She determined that the experimental group completed a larger percentage of the assignment than did the control group. The students who used the program indicated that they liked this form of instruction.

Moody (230) conducted an experimental study to evaluate the achievement of slow learners using a linear or a modified linear format to programmed instruction in BSCS Special Materials. Based on the study of post-test scores and the sub-test scores, the modified linear format was the more effective in terms of achievement.

A survey was done by Thompson (354) to investigate the extent of changes in the level of abstraction and the style of presentation in high school biology materials during 1960-68. Data from this study appeared to support the generalization that the differences in the nature of high school biology materials of the early 60's and the high school biology materials of 1968 were less than the differences between different materials within the respective periods of time. The 1968 materials were written at a slightly higher level of abstraction and they were less descriptive and more activity oriented.

Pottenger (269) used the theory of the disciplinary structuralists to evaluate the BSCS Yellow Version. He concluded that this version placed minimal stress on disciplinary structures. Like structures are preferentially attributed to the unified whole. The concept of biology as a composite of disciplines was found to be underdeveloped in the materials investigated.

Kastrinos and Voss (177) reported the results of a questionnaire given to students taking the College Board Achievement Test in Biology to determine which topics they remembered studying in their first-year biology courses. They concluded that remembered topics were highly correlated with textbook emphasis. The investigators also reported on the second phase of the questionnaire given to students taking the College Board Achievement Test in Biology to determine their laboratory background and classroom experience in their second-year biology course. They concluded the time spent in laboratory varied greatly and that exercises from other sources were frequently used as supplementary to the prepared textbook manual.

Holler (146) conducted a study to determine the readability of selected tenth grade biology text materials. The text chosen was Biological Science: Patterns and Processes. Using the Dale-Chall and Yoakam formulas and the cloze procedures he found that the text did not show a trend in readability from easier to more difficult materials and that readability limits existed when the text was to be used for below-average readers in the tenth grade.

Summary. Studies relating to materials were much in evidence during 1970. They stressed a varied approach and indicated that auxiliary approaches are an aid to learning. Nearly every study showed some significant difference in cognitive achievement when compared with traditional materials usage. An area not stressed but worthy of future study is the relationship between varied teaching materials and the achievement of affective objectives.

Methods of Instruction

Koyanagi (191) attempted to determine the relative effectiveness of two methodologies to improve seventh grade students' ability in problem solving. He found that lower IQ seventh grade students' abilities could be improved within a time limit of fifteen 40 minute periods of instruction utilizing either teacher planned or individually ascertained procedures.

Schuck (304) conducted studies on set-induction as an instructional strategy. Using the BSCS materials he found significantly greater achievement when teachers incorporated set-induction techniques. The purpose of set-induction was to focus the student on a path of orientation-- transition-- operation-- evaluation.

Wolfson (394) sought to determine the relative effectiveness of indirect/direct instruction on achievement and retention in chemistry and general science. The results indicated that a significantly higher achievement and retention of learning was generated by a teacher with a high I/D ratio as compared to a teacher with a much lower I/D ratio. Because not all groups showed the effect on achievement, but all did in retention, it appeared that retention tests were a better measure of this effect.

Airasian (6) studied the use of hierarchies in the analysis and planning of chemistry instruction. He found a high degree of agreement in hierarchy placement among teachers. The teachers' evaluative comments revealed many lower level cognitive behaviors and a lack of relationship between the content elements.

In a study by Jones and Blankenship (170) a correlation between biology teachers' pupil control ideology and classroom teaching practices was made. The classroom teaching practices were those recommended by BSCS. The study involved 168 teachers and 2,040 students. The use of inquiry methods in laboratory appeared to be less related to the teachers' pupil control ideology than the use of inquiry methods in other classroom activities.

Babikian (21) studied the relative effectiveness of teaching concepts by discovery, laboratory and expository methods. He found, by the measurements used in this study, that the expository method and the laboratory method were significantly more effective than the discovery method in overall achievement, verbalization of concepts, recognition of concepts, and application of concepts to numerical problems. Students found all three methods interesting, but somewhat surprisingly most of them considered the expository method the easiest, clearest and the best method for teaching science.

Zubulake (401) investigated the "learning by discovery" controversy. He used three seventh grade science classes and used discovery, guided discovery and programmed instruction as the experimental treatments. The findings of the study favored the guided discovery approach as an effective method of science teaching.

Dennison (92) compared the relative effectiveness of a verbal approach and a guided discovery approach to teaching of selected science principles at the seventh and ninth grade level of cognitive development. He found a significant difference favoring the guided approach for the seventh graders and the verbal approach for ninth graders. There was no significant difference in retention or transfer of learning with either approach.

Holford and Kempa (145) investigated the effectiveness of stereoscopic presentation in improving visualization of spatial relationships in structural chemistry. Two types of programs were employed, one with photographs and a lenticular stereoscope and the other with a single photograph. They concluded that the use of the stereoscope in both the program and the test led to significantly better test results.

Shafer (308) conducted a study to determine whether the use of the computer as a reinforcement tool and the use of the inductive method of instruction in the chemistry laboratory produce higher achievement scores than more traditional methods. The results of this study indicated that the inductive approach and/or the use of the computer in chemistry laboratory instruction increased the student's understanding of science significantly more than conventional methods.

Garren (114) investigated the hypothesis that tenth grade biology students could learn certain physics concepts interjected into a programmed unit of biology instruction. He concluded that the addition of physics as a complete course at the end of the biology course or as interjections at intervals throughout the biology course did not significantly change the success on either the factual, direct-recall or the functional, higher-level biology questions on either the achievement or retention tests.

Fulton (111) made a comparison of two methods of instruction in BSCS biology. The results favored the individualized approach to instruction. Students in this section achieved more, understood the meaning of science better, grew more in their ability to think critically, developed a better attitude toward the study of biology and rated the teacher higher in his ability to make the materials understandable, than did students in conventional sections.

Holliday (147) analyzed science instruction techniques using different media in learning and testing modes. This study involved 350 tenth grade biology students. Results indicated no advantage either in presenting the verbal information using a combination of audio and printed media simultaneously or in using the same media in the learning and testing session.

A study by Falls (105) was designed to determine the effects of research papers and reports on understanding science when used in secondary school physics. The study involved 200 students in Harvard Project Physics, with one group using the textbook and the other group using the Reader. Falls found that the group with the Reader scored significantly higher on understanding the nature and processes of science. The group that studied with the Reader also scored significantly higher on the Test On Understanding Science and exhibited greater conceptual-set after the study.

Thelen (352) conducted a study in the use of advance organizers and guide material in viewing science motion pictures with 349 ninth grade students. She concluded that the use of advance organizers and guide material when used alone or in combination did not result in statistically significant differences in learning. Students who did not use guides demonstrated a significantly negative change in attitude toward motion pictures as instructional tools.

Breedlove and Gessert (51) evaluated the use of an "Electric Blackboard" in the teaching of high school physics. The lectures originated from the university to student teachers working in the classroom. Students did significantly better on the post-test as compared to the pretest. There was, however, a significant number of students who did not like receiving lecture notes over the "electric blackboard".

Andriette (15) compared teacher demonstration and small group laboratory methods of instruction on the acquisition and retention of science knowledge. He found no significant difference in knowledge learning, but comprehensive learning was significantly improved.

Berne (36) analyzed the effects of different approaches to teaching on certain aptitudes using the Introductory Physical Science (IPS) course. He concluded that achievement in science was greatest among students of this "new" approach. The "new" approach also developed more significantly the aptitudes of verbal reasoning, numerical ability and space relations.

Summary. Studies of methods of instruction varied greatly. A great number of them were comparative in nature and stressed such methods as team teaching, problem solving, use of objectives, computer assistance, individualization and use of multi-media. It would seem that this continues to be one of the most popular areas of research. At the same time, really new and ingenious methods are lacking.

In many of the studies reported, lack of clarity with respect to validity and reliability of instruments used and the extremely short time range over which experimental factors were applied create real questions concerning the validity of results obtained. Conflicting results appear from seemingly similar studies. Historically, "methods" research has borne out the maxim that "any method works under certain circumstances and in the hands of a competent teacher". The body of research here reported seems not to refute that observation.

Laboratory Practices

Six studies are reviewed in the area of laboratory practices. A study by Shaver (309) dealt with the effect of laboratory teaching strategy on pupil task orientation. He used the Laboratory Interaction Analysis Instrument and the Internal versus External Control of Reinforcement Scale. The sample consisted of 44 students evenly divided into two sections. One strategy was inquiry-oriented and the other was teacher directed and controlled. The investigator concluded, among other things, that there was no significant effect attributable to laboratory practice on pupil task orientation and that there was a high correlation among the judges who rated pupil task orientation from student laboratory reports.

Charen (67) compared the effectiveness of the open-ended chemistry laboratory with the traditional laboratory on critical thinking. He found no significant difference as measured by achievement tests and the Watson-Glaser Critical Thinking Appraisal.

Norman (250) surveyed 133 secondary biology teachers to determine the suitability of various types of laboratory designs. Survey results indicated that the split lecture-laboratory design was the most effective for the instructional modes of independent study, small group instruction, and large group instruction. The most frequent recommendations for increasing effectiveness included more functional tables, ventilation systems, student stations, room darkening facilities, more storage space, more space for group and individual activities and more service outlets.

Best (37) made a study of the correlates of student decision making in the secondary school biology laboratory. She found that teachers were perceived as making about three times as many decisions as the students during laboratory activities. In only six of the 33 classes did the students perceive that they made as many or more decisions as did the teacher. She further found that student decision making was not significantly correlated with either the problem orientation or the students' perception of the student relationships.

Latham (201) surveyed the percent of instructional time spent in the laboratory. He found large variances, with 25 percent of the classes surveyed spending less than ten percent of the time and only thirteen percent spending more than half the time in the laboratory. The most frequent response was 20 percent. The percent also depended on the course being offered. The relationship of quantity of equipment and laboratory facilities to the amount of laboratory time was not significant.

A somewhat different type of study concerning a vital facet of science teaching was done by Brennan (52). It concerned safety in the high school science program. The purposes of the study were to identify the types of accidents and the areas in which they occurred in high school biology, chemistry, and physics laboratories, the contributing factors that cause accidents, and the preventive measures practiced and their success. Four-hundred thirty science teachers from all 50 states were surveyed. Some of the conclusions were: 1) there was little correlation of the number of years of teaching experience with the number of laboratory accidents, 2) there was no significant relationship of laboratory accidents with various school enrollment groups, 3) generally, remedial groups had less accidents than general accelerated or advanced placement groups and advanced placement groups in general had the most accidents, 4) class enrollments had a significant relationship to the number of laboratory accidents and as laboratory space was increased accidents decreased, 5) those laboratories in which the laboratory and classroom were in different rooms had the greatest number of accidents, and 6) fewer accidents occurred in laboratories with individual laboratory stations, and those schools in which safety programs were a part of the curriculum had less accidents than those without safety programs. Chemistry was more prone to laboratory accidents than either biology or physics.

Summary. Few studies were completed in the area of laboratory practices. Of the six studies, one was on facilities and two were of a survey nature. This would seem to indicate a satisfaction with the present laboratory setup. While surveys generally revealed areas of concern in the adequacy of laboratory facilities, research studies of facilities design and usage are sparse. This is somewhat surprising considering the emphasis on laboratory work by all the major science curriculum projects. It would seem this area of instruction merits serious consideration for future research.

Curriculum Studies

Seventeen studies were reviewed in the area of curriculum. These included the fields of biology, chemistry, physics, earth science, and innovative efforts. Obradovic et al. (255) attempted to identify the factors affecting the implementation of new science curricula. The study indicated that effective implementation of new curricula required the provision of assistance and support to curriculum personnel, a total curriculum plan, appropriate in-service education, continual curriculum evaluation and curriculum revision.

Wixson (393) examined the effect of a mathematical approach to teaching cell structure and physiology and the probability aspects of genetics on student achievement and attitudes. He found that the variation in approach had no effect on students' attitudes on the place of mathematics in society, but that there was a lateral transfer effect in the achievement scores on the topic of the cell and a vertical transfer effect on the achievement scores on the genetics topic.

Two investigators made evaluations of the BSCS curricula. Strauss (337) designed a system for analyzing research reports and concluded that the case for BSCS has yet to be proved. Mayer *et al.* (219) made an evaluation of *Biological Science: Patterns and Processes*. He found a significant correlation between reading comprehension and achievement.

Hardy (132) analyzed the achievement and level of critical thinking of students in CHEM study and traditional chemistry. He used 208 students in ten chemistry classes and found that students in CHEM study achieved the objectives better than those in a traditional class. He also found that there was no significant difference in the effect on critical thinking between the two approaches.

In another study, Ramsey (274) designed an instrument to investigate the development of chemistry content by CHEM study teachers. Common patterns of content development were identified. The results of the study suggested that the teachers in the sample adopted a deductive teacher-oriented approach to teaching chemistry content.

Lewis (204) made a study to determine if training in visual space perception could alter achievement in the study of waves and optics. The results of the study showed that there was a significant increase in the visual space perception of the students who were trained in this aptitude. The study failed to show a transfer of learning to alter achievement on the topics of waves and optics.

In another study, Schneiderwent (303) explored the effect of using behavioral objectives on the cognitive achievement of 341 students in Harvard Project Physics. The experimental method of instruction proved to be more effective than the conventional method of instruction for boys, but both methods were equally effective for girls. Boys achieved significantly higher in both groups.

Poel (268) studied the relation of critical thinking to PSSC and non PSSC physics programs. He found little evidence to support the belief that either the PSSC or the non-PSSC courses were more effective in developing critical thinking.

A survey by Bila and Bligh (38) involved 112 schools and 4,965 students. They found that 46 percent of the schools used the *Modern Physics* text by Dull, Metcalf and Williams and 37 percent used the PSSC materials with the most common time interval being 55 minutes five periods a week.

Several studies dealing with the Earth Science Curriculum Project (ESCP) were reported. Henson (142) made an effort to identify the earth science principles pertinent to the general education programs in junior high schools. He presented the procedures used to identify principles in astronomy, geology, meteorology, oceanography and physical geography. The study resulted in a list of 108 earth science principles ranked on an investigator-constructed scale.

Flores (109) reported the results of a questionnaire sent to teachers who were involved in a National Science Foundation Earth Science Institute. Data were tabulated for regional areas of the United States concerning earth science enrollment, grade level, laboratory course, field trips, advanced courses and student interest.

Henson (143) studied the achievement of ESCP students from different socioeconomic backgrounds. He found a significant difference between the upper and middle groups as well as between the upper and lower, and concluded that more appropriate materials should be provided for the lower socioeconomic students in the Earth Science Curriculum Project.

In an effort to study the reaction of pupils to the Nuffield Science Teaching Project Trial Materials, Meyer (224) studied 1,226 Fifth Form (Grade 11-12) pupils. He concluded that boys were more interested in the materials than were girls. The Nuffield Project produced an improvement in science attitudes for girls, but not for boys. The study also showed that the Nuffield Project was most influential in the improvement of over-all scientific orientation, even though the influence in physics was negative for boys.

Bingham et al. (41) reported on the Demonstration of an Improved Science Curriculum for Underachieving Students (DISCUS) program. This report was based on the premise that if underachieving junior high school youth are separated from their more successful peers and provided with a series of meaningful activities using a directed discovery approach, an improvement in their attitudes toward themselves, their teacher, and their school will be displayed. The study indicated that a preferential treatment of disadvantaged students in success-oriented science classes improved their attitude toward the school and school personnel and this growth continued when the student was given relevant small group laboratory activities.

Durst (100) compared three courses of physical science; namely, traditional physical science, Interaction of Matter and Energy (IME) and Introductory Physical Science (IPS). This study indicated that students in IME scored highest on the Test On Understanding Science and on the Iowa Test of Educational Development, while students in the traditional program scored highest on the Science Research Associates Achievement Series.

A somewhat different study was conducted by Mount (238), whose purpose was to develop for those interested in secondary school science, sequence information concerning grade placement level for high school physics, diffusion or integration of physics with other sciences and methods to use to increase physics enrollments. Information was obtained partially through the search of related literature and through the analysis of data concerning physics enrollments. Conclusions were: 1) that there was no scientific research found to justify limiting physics to juniors and seniors, 2) other selected nations provide physics for their pupils before they reach the secondary schools, 3) some schools in the United States have reported successful fusion or integration of physics, chemistry, and biology, 4) statistical analysis of data showed no significant difference between the achievement of sophomores and juniors and seniors, and 5) statistical analysis showed a highly significant increase in physics enrollment when sophomores were permitted to enroll in the course.

Summary. Most of the studies relating to curriculum dealt with a review of the older curriculum projects. Very little effort was made to design new and alternative suggestions. Efforts in the area of humanistic science for today's schools are needed.

Teacher Education and Teacher Traits

Bartholomew (27) attempted to determine the effect of earth science instructional models on the investigative teaching behavior of experienced science teachers. His purpose was to ascertain if experienced science teachers would modify their teaching behavior after observing and studying an instructional model. Twenty-seven experienced science teachers participated in the study. The investigator found that teachers did change their investigative teaching behavior after seeing an instructional model. Teachers viewing a videotaped instructional model immediately prior to teaching had the greatest immediate gain in investigative teaching behavior. Television teaching techniques in a microteaching format were found to be effective in changing the teaching behavior of experienced science teachers.

In another study of changes in teacher behavior, Jackson (157) attempted to evaluate the effects of an inservice program on the behavior of earth science teachers. The program had a ten week summer course that emphasized content and local field studies. It was desired to change teacher behavior to a more laboratory oriented approach. The investigator found that teachers changed the way they thought they were teaching toward an inquiry approach following the inservice program. This study indicated again that positive results usually can be obtained in a specific goal directed type of activity.

Zurhellen (402) evaluated attitude changes among science teachers during an ESCP inservice institute. The purpose was to ascertain the attitude changes of science teachers in a concentrated academic year earth science institute. Seventy-five teachers and 20 leaders were involved in the year long program. Some characteristics of group leaders exerting the greatest positive influence in bringing about attitude changes were identified. Among these were high self opinion and high congruency of self perception with the teacher's perception of the leader.

A study by Osborn (258), while having a rather local origin in a single state, can probably be generalized to a larger population. Osborn attempted to determine the qualifications of biology teachers and to investigate the relationship of student achievement in biology to the subject matter preparation of the teachers. A positive relationship was found between student achievement in biology and the teacher's preparation in the biological sciences. Also, a positive relationship was found between student achievement in biology and the biology teacher's preparation in chemistry. It appeared that the most effective biology teachers had taken a minimum amount of work in the biological sciences and a substantial amount of work in chemistry.

In another study of biology teachers, Norris (251) attempted to measure the self-concepts of secondary biology teachers and their relationship to student achievement and to other teacher characteristics. Thirty teachers who had attended an NSF Institute and 1,400 of their students comprised the study group for this investigation. Significant correlations between certain aspects of the biology teacher's background and his self-concept could be discerned. The study supported the hypothesis that a significant relationship exists between the teaching proficiency of a biology teacher and his self-concept, his biological knowledge, and between certain aspects of his background and characteristics. There was a positive relationship between the biology teacher's self-concept and the number of semester hours of psychology, education, and student teaching, as well as to the number of years of teaching experience and to the number of dependents.

Three studies of verbal behavior of teachers were reviewed. In the first of these, Miller (226) attempted to design a usable and valid ver-modern verbal interaction analysis instrument and to explore the verbalizations taking place in a ninth grade physical science class using the instrument. The usefulness and validity of the instrument were determined through the use of two groups of ninth grade physical science teachers. The instrument was subsequently found to be able to detect statistically significant differences in six out of nine categories of verbal behavior.

The second study on verbal behavior was done by Collea (78). His study measured changes in intentions, self-perceptions and role perceptions of beginning science teachers. Twenty-five first year science teachers comprised the sample. Conclusions indicated that changes in the way first year science teachers perceived how their principals wanted them to behave in the classroom were conflicting. Changes in intentions of first year science teachers were also conflicting. By the end of the school year, beginning science teachers perceived themselves as being more direct in their classroom verbal behavior. A final interesting conclusion was that role perception of first year science teachers and the ideal teacher perceptions of their principals were farther apart at the end of the school year than at the beginning of the school year.

Glass (118) studied the effect of teacher behaviors on student behavior. His sample contained 525 high school biology students. The results of this study indicated that students in general tended to adopt an attitude towards biology similar to that of their teacher. However, the possession of a stated attitude towards biology which was similar to the stated attitude of the teacher had little relationship, if any, to subsequent achievement in biology.

Characteristics of effective science teachers were studied by Halterman (129) using a Q-sort technique. Biographical data were collected from the teachers. Students and principals rated the teachers on effectiveness. Halterman concluded that the Q-sort technique proved useful; that considerable diversity existed between the judgements of science teachers, principals, and students concerning teaching effectiveness; and that biographical data contributed more than the other variables used for assessing the characteristics of effective science teachers.

Snider (326) studied the leadership role of secondary science teachers as it related to the science program. His sample included nearly a thousand science teachers, principals and supervisors. The investigator concluded that principals and supervisors were more positive about the contributions of science teachers as leaders in science education than were science teachers themselves. Science teachers believed that the greatest obstacle to be overcome to enable the science department to become more successful was the excessive teacher load. Principals and supervisors felt that inadequate budgeting for the science department was the greatest obstacle.

Summary. Studies of teacher education were varied in scope and direction. Attitude and behavior changes were investigated in several studies. Results indicated attitudes and behavior can be changed by direct attention to them in in-service or institute courses. Verbal behavior of teachers was a focus of other studies, although the tested methods of interaction analysis were not used in those cited. Perhaps the difficult problems involved in usage and interpretation of various interaction instruments have discouraged their use. A simple but effective instrument for classroom interaction analysis still eludes the researcher and practitioner.

Measurement and Evaluation

The section on measurement and evaluation deals with all aspects of measurement. It includes instrument development, program effectiveness, objectives, taxonomies and instrument design.

Podrasky (267) constructed and validated an experimental test that would require students in introductory physics to use graphic rather than verbal skills in identifying relational concepts. The effectiveness of the test was examined with two types of programs, traditional and contemporary - PSSC physics and involved 226 students from four schools. The Kuder-Richardson - 20 estimate of reliability was .726. Podrasky found that the experimental test scores and scores for verbal knowledge of physics were more highly correlated for the traditional-physics students than for the contemporary-physics students.

Schaff (293) developed an instrument to measure the cognitive evaluation ability in chemistry students. While there was no difference in knowledge ability with a modern or with traditionally taught course, there was a significant difference in the evaluation ability of the students in the modern course.

Benson (35) developed an instrument which was based on the Assessment of Cognitive Transfer-An Evaluation Instrument for Secondary Biology Teaching. It was written using a branching program format centered around nine structurally related biology situations. The Assessment of Cognitive Transfer in Science Inventory (ACTS) was classified by cognitive category using a scheme unique to science but patterned after Bloom's Taxonomy of Educational Objectives. The instrument has a reliability of .86. Analysis of the data stressed nonparametric statistical procedures. The five classes tested did not differ with respect to performance on the total ACTS Inventory. Performance of students by level of performance on ITED Test 6, a measure of critical thinking in science, was positively correlated with performance of students by level on the total ACTS Inventory.

Cillizza (72) developed a critical thinking battery which was designed to measure a number of primary factors involved in the ability to think critically. The battery was designed for students in grades 7-8. While performance on the test was related to general reading ability, there was no significant relationship with chronological age or with grade level. The relationship to intelligence tests was positive.

In an effort to relate classroom tests to transfer of learning, Demchik (91) gave two tests to chemistry students after they had completed a programmed instruction unit. The experimental test was based on Bloom's taxonomy and discriminated between higher and lower cognitive levels and categories. Demchik found a significant difference between the two tests and that the experimental test had discriminating power between higher and lower cognitive levels.

Hungerford (152) developed an instrument to measure the science skills of observation and comparison. The test was validated at the junior high school level. All samples, regardless of race or cultural background, improved significantly in both skills as a result of training.

Smith (321) developed a classroom observation instrument to investigate teacher and student behaviors associated with the maintenance of an inquiry atmosphere where Earth Science Curriculum Project materials were used as a course of study. Behavioral items were written as potential indicators of one of three categories of activities: activities consistent with maintaining the inquiry atmosphere of the ESCP materials, activities neutral to the ESCP approach, or activities inconsistent with an inquiry approach. Teacher and student behaviors were then grouped into four major categories consistent with settings expected to occur in ESCP classes, i.e., developing text material, prelaboratory, laboratory, and postlaboratory discussion. A panel of seven judges rated each item as 1) consistent with ESCP, 2) neutral, or 3) inconsistent with ESCP. The instrument, refined on the basis of the ratings, was then used to observe teaching situations. When all observations were pooled across the four classroom settings, the inter-observer agreement was P = 74%.

Kaiser (173) conducted an exploratory study to design an observational instrument for describing teachers' activities and behavior when using the CHEM study materials. He found that the instrument produced data which pointed out differences in teacher behaviors for two teachers whose training in chemistry and teaching experience were similar. Kaiser suggested that when the instrument developed is used with studies of student outcomes the aspects of teacher behavior may be correlated with student behavior, achievement and interest.

Mullen (239) conducted an evaluation of Quantitative Physical Science (QPS) and developed an inexpensive and reliable procedure for conducting similar type studies. He concluded that the students who took QPS were found to be more motivated and that they achieved in future science and mathematics courses at a significantly higher level than those who had a course using the state adopted textbook.

Three evaluation-type studies were completed on different types of programs. Welford (380) conducted a study to evaluate the effectiveness of instruction in high school biology in a conventional course and the Special Materials course for slow learners in terms of achievement and interest of the slow learner. The data indicated that there was no significant difference in either the achievement or the interest of the students.

Harke (133) described two methods of hierarchical analysis used to measure the similarity of sequence in the randomized multiple choice and free-response problem test format. The results indicated that the responses of the subjects as a whole validated most of the dependency relationships within the hierarchies. The students were probably required to use the same problem solving skills and procedures. This revealed the amount of similarity between sequences of physical and mathematical concepts in problem solving.

Grgurich (127) evaluated the achievement of general course objectives in secondary school biology for students of different ability groups. Although he encountered varying degrees of success, he concluded that pre-determined general course objectives for given ability groups of secondary students exposed to selected biology courses could be taught for and achieved.

Even (104) studied the relationship of teacher-assigned grades in high school chemistry to taxonomy-type objective test scores. He found that teacher-assigned tests are not highly related to the Ontario Test of Achievement in Chemistry (OTAC), but he was able to isolate groups of students in which different combinations of the predictor variables functioned most effectively.

Bryant (55) examined the effects of expressing course objectives in specific behavioral terms on achievement level of low achieving eighth grade science students. He observed that the teacher remained the important factor in determining the success or failure of pedagogical techniques used in training the low achiever. The use of performance objectives appeared to facilitate the presentation of course content in small manageable pieces thus providing greater opportunity for the low achiever to experience success in the classroom.

In a study by Broadhurst (54), the procedures and results of an item analysis on the Watson-Glaser Critical Thinking Appraisal Form Ym were presented. The results, based on the response of 200 graduating high school students, indicated that the test was not as valid a measure of critical thinking ability as desired.

Jones (166) evaluated the impact of the Secondary Science Training Program sponsored by the National Science Foundation. He used Osgood's semantic differential system and found a positive difference in the positive direction on "four-year college" and "senior extra-curricular activities" by the experimental group. These findings suggest the need for additional involvement of returning participants in senior year curriculum planning to maximize the effect of the summer program.

Good (122) made a comparison of self-graded and teacher-graded achievement in a BSCS secondary school biology course. He found no significant difference in achievement as measured by a standardized exam, but the self-graded group produced a significantly higher number of reports with a larger percentage being based on research. The self-grading model seemed to have the degree of validity and reliability adequate for self-grading in the BSCS biology course.

Kvidahl (197) conducted a study to determine the differences between teachers' self-evaluation of their teaching effectiveness and their senior-class students' evaluation of their effectiveness. The composite self-evaluations of all teachers tend to be similar to their students' evaluation. The ten areas of rating produced agreement on "Knowledge of the Subject" as the most important trait and "Personal Appearance" as the least important trait.

Summary. A major concentration in the development of new instruments of evaluation is presently occurring in areas such as critical thinking, the affective domain, and achievement. There was very little concentration on the psychomotor domain, communication, or creativity. A major effort of evaluation seemed to be based on self-grading and self-evaluation. A great deal of work in these areas is needed and competency-based evaluations need to be stressed.

Individualized Instruction

There are six studies related to various aspects of individualized instruction. Krockover (194) compared learning outcomes in the Chemical Bond Approach (CBA) chemistry when group and individualized instruction techniques were employed. The individualized self-pacing approach centered on the use of the laboratory. The results of this study indicated that CBA chemistry can be individualized in a purposeful manner for classroom use. Furthermore, individualization did not reduce the chemistry achievement, understanding of science, or the critical thinking ability of the students.

Conlon (80) conducted an investigation to determine if providing seventh grade students with objectives of instruction altered performance. The objectives used were those of the ISCS field trial. The results indicated that those students with prior knowledge of the objectives performed slightly higher than those without knowledge of the objectives, but this was not significant at the .05 level. Within the limits of the study, the findings challenge the premise that knowledge of objectives for a highly structured instructional sequence such as ISCS significantly alters student performance.

Williams (389) did an experimental investigation of the instructional effectiveness of individualized versus group instruction in the teaching of Quantitative Physical Science (QPS). A total of 192 students were involved; 64 control, 64 experimental, and 64 in a reference group (not involved in Quantitative Physical Science but taking a different course in physical science). The study tested the null hypothesis: that no significant differences existed between the sample means for achievement, retention, and the time required to complete activities. Williams concluded that: 1) so far as achievement on semester examinations, standardized tests, and semester grades were concerned, individualized instruction was more effective than group instruction for most students; 2) so far as retention was concerned, based upon pre-test and post-test scores of Comprehensive Test in Basic Physical Science, individualized instruction was significantly more effective than group instruction; 3) with the same subject matter content, a student on individualized instruction completed 8.1 percent more activities than those students involved in group instruction; 4) so far as student reaction to individualized instruction was concerned, most students felt they learned more, enjoyed it more, and made better grades when involved in individualized instruction; and, finally, 5) individualized instruction was more effective for all levels of potential achievers than group instruction.

Dagenbrock (86) conducted an investigation to determine the validity of the use of computer assisted instruction (CAI) as a tool in formative curriculum evaluation. The results indicated that CAI and non-CAI students' performance was similar within the ISCS materials.

Peterson (264) studied the development of a conceptually oriented curriculum framework in science for grades seven through nine. He made an effort to analyze change in the acquisition of subject matter between individualized and lecture-demonstration patterns of instruction. The study showed that the students in individualized instruction had significantly higher gain scores on achievement tests.

Glass and Yager (120) also made a study of individualized instruction as a spur to understanding the scientific enterprise. Results indicated students who solved problems individually or in small informal groups understood science and scientists better than did those who solved the problems as a class group.

Summary. Individualization was a key word in the late 60's, although the number of secondary studies reported does not yet indicate a large research interest. Considering the prevalence of the concept of individualization in the literature, it is likely the number of studies related to some aspect of individualization will increase markedly in the near future.

As a very tentative generalization based on the limited studies reviewed, it appears that cognitive achievement does not suffer in individualized modes of instruction, and increased interest and favorable attitude changes frequently accrue.

Processes in Science

In a study by Okey (257), the purpose was to see if the inability to perform a task was attributable to failure on the skills subordinate to it. One-hundred thirty-five tenth, eleventh, and twelfth grade chemistry students were studied. It was concluded that adding instruction on subordinate skills in a science learning program was successful in significantly improving the performance on the criterion task.

Ashenfelter (17), using five case studies, investigated the problems experienced by beginning chemistry teachers as they attempted to help their pupils use data or draw conclusions. In this study the subjects often demonstrated that they did not clearly understand that the major purpose of performing a laboratory investigation was to gather clues for theorizing. Subjects' failures to use orderly problem solving approaches were attributed to lack of practice in learning problem solving and to the fact that problem solving in undergraduate chemistry courses was frequently done by imitating type problems rather than applying problem solving strategy. It was recommended that prospective chemistry teachers should receive explicit instruction on the purposes of performing laboratory investigations and that their assigned experiments should help reinforce that instruction.

Starr (321) investigated behavioral outcomes related to science processes of ninth grade BSCS students. His purpose was to analyze the use of "Invitations to Inquiry," and to assess the effect on critical thinking, knowledge of processes of science, and attitude toward biology of ninth grade BSCS biology students. One-hundred thirty-two students participated in the study. Starr found that utilizing invitations to inquiry improved the critical thinking ability of ninth grade students, but did not improve or hinder the attitudes of these students towards biology.

In a study, by Karplus and Peterson (176), on intellectual development beyond the elementary school, the problem was to survey students' abilities to apply the concept of ratio and proportion in a problem. A total of 727 students of age levels nine through eighteen participated in this study. Karplus and Peterson concluded that successful proportional reasoning was not achieved earlier than the last years in high school. The implication was that there is a serious gap between secondary school mathematics and science curricula and the student's reasoning ability.

Summary. The fact that there were few studies related to processes in science at the secondary level suggests both an apparent lack of interest and a need for more research in this area.

Inquiry Teaching

A number of studies involving the processes of inquiry were reported. In the first of these, Bills (40) attempted to increase divergent thinking of students, in a five-week experimental treatment utilizing student inquiry. There were 300 students involved in the experimental and control classes for this study. The experimental treatment consisted of an inquiry session in which the demonstrator showed a discrepant event and students then suggested hypotheses to explain the demonstrations. The manner of questioning followed the pattern of J. Richard Suchman's inquiry development program. Results indicated that the experimental treatment did not significantly increase the creativity productions of the subjects and creativity was, therefore, not increased as a result of the experimental treatment.

Kitko (184) compared students' gain in understanding selected concepts of science in high school physics lessons which differed only in the amount of inquiry orientation used. Two sets of lessons involving six principles of physics were taught. The main difference in the two treatments was the opportunity for students to ask questions in the inquiry mode, whereas they were primarily lectured to in the traditional mode. The results indicated that secondary school science teachers should not be dissuaded from using inquiry oriented procedures, as the differences between the means of the crude gain scores of the two treatment groups were not significant.

Steiner (333) attempted to determine the relationships of certain practices of high school biology teachers to student performance of inquiry process behaviors in the affective domain. Forty-three high school biology classes were used in the study. The teacher practices which correlated the highest with student inquiry performance were: 1) having students read the original writings of scientists, 2) allowing students time in class to discuss ideas, 3) showing students how to ask questions of the text, 4) readily admitting mistakes, and 5) asking students questions which require them to think of evidence behind the statements in the textbook. A general conclusion was that teacher practices involving student participation in the classroom exhibited the highest relationship to student performance on measures of affective inquiry objectives.

The role of questioning in inquiry teaching was investigated by Ladd (199). Using 40 ninth grade earth science classes, the investigator found that teachers who asked a greater proportion of higher inquiry questions caused a greater change in students. Achievement of students was measured by a post-test examination which was a modified Smith and Meux Question Classification Scheme.

The relationship between inquiry teaching and intellectual development was studied by Friot (110) who used certain study tasks described by Piaget and Inhelder to evaluate changes in reasoning ability. The taks evaluated the development of interpropositional logic, i.e. formal operations. It was found that some curricula were effective at some grade levels and not at others. The Time, Space, and Matter curriculum was significantly more effective in enhancing the development of formal operations than were either Introductory Physical Science or Earth Science Curriculum Project materials.

Thomas and Snider (353) investigated the effects of guided discovery versus didactic methods upon the acquisition of certain inquiry skills. Also, the effects of method on the attainment of factual conceptual achievement were assessed. One-hundred forty eighth grade students were used during a six week period on the subject matter "Early Man in America." The results indicated that the didactic group did better in factual conceptual achievement and the guided discovery group did better for the acquisition of inquiry skills.

Summary. Studies of inquiry teaching were complicated by lack of clear definitions of this instructional mode, although the emphasis on student questioning seemed to be a fairly common thread. On the basis of a very limited number of studies, it appears that affective objectives and skill objectives were satisfactorily achieved in inquiry teaching, and that cognitive gains were at least equal to those obtained by conventional methods of teaching.

Comparative Studies

This group of studies is divided into subject areas of general science, earth science, biology, chemistry and physics. In the general science area, Teates (351) compared the performance of ISCS and non-ISCS ninth grade students on several Piaget-type tasks. Nineteen conservation tasks using color slides and recorded tapes were administered to about 250 ISCS and non-ISCS students respectively. Students were divided into high, medium, and low abilities on the basis of standard mental ability tests. There was no difference in the performance of students of the ISCS or the non-ISCS groups on the tasks test, but in both treatment groups, higher ability students performed better than lower ability students.

Kline (185) studied the relationship between self-directed and teacher-directed eighth grade students in an open-ended ESCP laboratory block. Ninety-seven students were involved in the study. The results showed no significant difference in cognitive understandings of the lab block between teacher-directed and self-directed students. This indicated that junior high students are capable of independently using self-directed, open-ended blocks as supplementary materials. Ninety-six percent of all the students in the study stated a very high interest in working with the materials and 90 percent indicated they would like to do additional work with similar lab blocks. The results indicated that the development of other lab blocks would be valuable, in view of the trend in science toward more use of independent study.

Agne (5) compared classes in earth science that used original data in a research approach with classes taught by conventional approaches and not using such data. His purpose was to determine whether the teaching of meteorology and climatology by the use of original data might result in greater student critical thinking. Thirty classes in each group comprised the sample. The data centered approach effected a significantly greater improvement in critical thinking by students than was achieved by students in the earth science classes not using such an approach.

In a study of students' understandings of science, Sheppard (311) attempted to determine junior high school students' understanding of the scientific enterprise, the methods and aims of science, and of scientists. The study compared the Earth Science Curriculum Project and the traditional approach to general science teaching. Results indicated that the two methods of teaching junior high school science produced significant differences in all areas of student understanding. The methods and aims of science, the scientific enterprise, and the scientist all received higher mean scores from the Earth Science Curriculum Project sample of the tests for student understanding of these areas. Evidence indicated that students who were involved in experience type approaches to science, had a better overall understanding of science than those students who were taught by a traditional approach.

A comparative study in biology was done by Jones (169). One-hundred five secondary schools participated in the program. The results suggested that in classroom activities the teacher who has a more humanistic pupil control ideology exhibits to a greater extent the classroom teacher practices recommended by BSCS than does the teacher who has a more custodial pupil control ideology.

Driver (99) investigated the associational factors between biology teacher beliefs and student expression on understanding science and implications made by students relative to science facts. Here the results indicated that students who studied biology under the teachers who were identified as experimental, made superior scores on both the Test On Understanding Science and the Facts About Science Test. It appeared that what a biology teacher believes about experimentation in science tended to influence student outcomes in science. Open-minded, experimentalism-prone biology teachers consciously or subconsciously created an atmosphere more conducive to learning science than did teachers who did not hold strong beliefs toward experimentation.

In chemistry, Troxel (357) compared the student achievements on the common objectives of CHEMS, CBA, and "Modern Chemistry" (Holt, Rinehart, and Winston) courses. The results of this study indicated that the three courses were not equally effective in meeting their objectives. CHEMS and CBA developed a better understanding of chemistry and science and developed greater ability for critical thinking. CBA students liked science less than did students in the other courses.

Denny (93) attempted to determine what mathematics competency was necessary for students to succeed in chemistry. An analysis was made of chemistry texts copyrighted 1960-1970. Ten mathematical skills used by all the texts were identified. To ascertain the presence of these skills in the students, the Mathematics Skill Test, MAST, was composed and validated. The reliability and validity information on this test appeared to be extremely thorough. It was concluded that MAST could be used as a valid means for discerning students' needs, thus providing an empirical basis for future chemistry instruction.

Diamond (94) compared achievement in CHEMS and traditional high school chemistry courses based on the students' perceptions of their motivation for studying the subject. This was a questionnaire study with a major purpose to examine eleventh grade students' perceptions of their motivation for the election of high school chemistry. A cooperative examination in high school chemistry (Form 1969 of the ACS) was used to determine the understanding of basic chemical concepts and the acquisition of skills in problem solving. The Test On Understanding Science was used to evaluate student understanding of the scientific enterprise and the aims and methods of science. Two conclusions were cited. The first was that the majority of students elected to study chemistry for reasons other than pre-professional purposes or interest in the subject as a discipline. Second, the traditional curricula were more effective than CHEMS curriculum for teaching chemistry to highly motivated students with pre-professional interest in the subject and for developing understanding of science and scientists in students with a cultural interest in chemistry.

Schmitz (302) compared the relative effectiveness of utilizing two types of student participation in laboratory activities in teaching dimensional analysis in high school physics. Seventy-two junior and senior students from five high schools were divided into two groups, the manipulative group and the non-manipulative group. The first actively manipulated and had direct contact with laboratory equipment, whereas the non-manipulative group viewed specially prepared photographic slides of the same laboratory exercises as those performed by students in the manipulative group. Results indicated that it was feasible to teach dimensional analysis to both groups of students using the lessons specially prepared for this teaching program. However, the level of achievement in utilizing the elements of dimensional analysis attained by students in the manipulative group was significantly greater than that obtained by students in the non-manipulative group. It was generally concluded that the manipulative laboratory activities used as a part of this teaching program contributed significantly to the level of achievement attained by students.

Dietrich (95) compared selected secondary schools having high percentages of physics enrollment with those having low percentages of physics enrollment. In the schools compared, a total of 36 teachers of physics, 175 physics students, and 173 twelfth grade students who were not taking physics comprised the sample. In the results, many comparisons are cited, some of which are the following: The typical high percent enrollment school had a larger enrollment in grades ten to twelve, had a larger percent of 1969 graduates who went on to four year colleges, had a smaller percent of 1969 graduates who terminated their formal education with graduation from high school, was more likely to provide the student an opportunity to take physics before the twelfth grade, offered more courses in physics, and reported more science and fewer mathematics courses as prerequisites to the physics course than did the low percent enrollment schools.

In a similar study, Van Koevering (361) attempted to ascertain the distinguishing characteristics of high schools with high and low enrollments in physics. He found that only a small percentage of students indicated that the physics teacher had either a positive or negative influence on their decision to take physics, that guidance counselors were more stringent than physics teachers with regard to the mathematics prerequisite, and that physics grades were in all cases lower than the grades that students received in their other academic subjects.

Summary. Comparative studies by their nature vary greatly in their content. Many studies in other sections could correctly be called comparative, but those cited in this section seemed to exhibit dichotomous approaches to teaching or laboratory work, or compared conditions in schools of widely different enrollments. It is impossible to generalize on results, but specific findings are found in the reviews of the studies.

COLLEGE LEVEL

Teacher Education: Courses or Programs

The following four papers all involve courses or programs in teacher education. The first study by Sagness (292) compared two pre-service teacher education programs. One program emphasized classroom participation in schools of two different environmental settings, urban and suburban, prior to student teaching. The other program (non-project) was developed around methods courses and other university based courses with few participatory experiences in the public schools prior to student teaching. The sample was composed of 98 secondary teachers in science education. Some conclusions were: 1) the project participants had significantly greater knowledge of culturally deprived students at the end of the first professional quarter than the non-project people, 2) the project student teachers held less positive views of culturally deprived students and of the type of activities which should be used for science instruction in an urban setting, and 3) the project student teachers used significantly fewer of the type of activities thought to positively implement the general objectives of science education than did non-project student teachers.

A study by Avdul (19) was designed to 1) examine the status of teacher training preparation in the new elementary science programs in methods classes of institutions in Ohio, Kentucky, Pennsylvania, and West Virginia, 2) identify characteristics of the methods courses and 3) examine opinions of the instructors about the new science programs. Results of the study showed that 1) the AAAS, ESS, SCIS, MINNEMAST programs are the most widely taught new courses in the methods classes and 2) institutions with greater enrollments expended more for science than smaller universities.

The purpose of a study by Christman (70) was to determine whether the elementary education majors taking a professional course in the teaching of science differed from the non-education majors taking a comparable level content course in science related to the elementary curriculum and their evaluation of science teaching methods. The investigator administered pre- and post-tests to all 215 subjects and randomly selected 35 subjects from five sections for his study. There were two major conclusions: 1) elementary education majors learn as much science content related to elementary school science while taking a science methods course as non-education majors enrolled in a science content course, and 2) changes in the methodology of teachers occurred on certain specific teaching practices both among subjects who studied a science methods course and among subjects who studied a science content course.

Griffiths (128) attempted to evaluate a previously developed combined course in physical science contents and methods. A study group made up of students taking the combined course in physical science content and methods was compared with three other groups. While all groups taking the physical science content course showed significant gains in scores from pre- and post-tests, there was no significant gain made by the study group. The study group made the greatest increase in correlation with the judges so as to be more like the idealized teacher. Students in the study group were found to have more confidence in their ability to teach science and more enthusiasm for teaching it.

Teacher Education: NSF Programs

The following four studies were directly related to NSF programs. The first study, by Drew (98), dealt with a national survey of the allocation of funds to colleges by the College Science Improvement Program (COSIP). Of 94 colleges eligible to receive COSIP grants, 29 were awarded them. To collect information on student characteristics, questionnaires were sent to students of the eligible institutions when they were freshman and again when they were seniors. Institutional characteristics such as enrollment, selectivity level, percentage of Ph.D.'s on the staff, and number of volumes in the library were included in the analysis in an attempt to identify variables which were related to subsequent receipt of a grant. The percentage of Ph.D.'s on the staff had the most significant correlation. Grant recipients were very likely to be non-sectarian liberal arts colleges which were relatively progressive.

A study by Irby (154) presents the results and conclusions of a survey of 120 participants of the 1961-65 academic year institutes at the University of Mississippi to determine 1) the participants' employment status one to five years after the institute; 2) the extent to which participants had continued their formal education, secured advanced positions, and changed schools; and 3) the participants' evaluation of the institutes curriculum. Among the conclusions were: 1) teachers used the institute training in their teaching and the benefits were transmitted to their students; 2) participants experienced wider opportunity to use their abilities and assumed positions of leadership, with a strong shift to college teaching; 3) participants have benefited financially; 4) the institute program created a strong interest in advanced degrees and additional academic work; and, 5) there was substantial evidence to indicate that the institute program could provide for the upgrading of science and mathematics teachers' competency. However, several factors tended to minimize the Institute's contribution to the improvement of secondary school science and mathematics teaching: 1) the chronic academically deficient teachers were systematically excluded (records must provide evidence of graduate potential); 2) the best academically prepared teachers were selected as Institute participants; 3) the shift of Institute participants from secondary schools into college teaching positions (43 percent); and, 4) the relative number of participants in comparison to the total teaching population. One conclusions was definite however, teachers selected as participants have greatly benefited from the Institute program.

Sutherland (342) attempted to answer the question: "Do National Science Foundation academic year institutes for earth science teachers serve as effective means for improving teacher's subject matter knowledge of earth science?" The population consisted of 33 NSF academic year institute participants from two 1969-70 institutes for earth science teachers. Analysis of data indicated that NSF academic year institutes for earth science teachers were effective means of improving teacher content competency in the area of earth science.

A study by Slawson (315) presented the results of a follow-up study of the academic year institutes in science conducted at the University of Virginia between 1957 and 1967, and reported the objective of the NSF academic year institutes to improve the overall quality of science education was accomplished. There were several conclusions drawn from his study. Among these were: 1) there was a high rate of retention of former academic year institute participants in the field of education, 2) exactly one-half of the responding participants were still engaged in the teaching of science in the public schools; the majority of the remaining half were functioning in related educational positions, and 3) the former participants felt the academic year institute experience had made a very definite contribution toward improvement of the quality of science teaching in the nation's schools.

Teacher Education: Attitudes

Five teacher education studies dealt with attitudes. King (183) examined student teacher changes in beliefs and practices related to teaching elementary school science. The investigator developed and used a Q-sort deck of 65 belief statements about science teaching practices to identify the participant's belief about teaching science. Three university instructors who had taught the undergraduate science methods course, 20 elementary education majors who were assigned to student teaching in the fall semester of 1969, and each of the 20 supervising teachers assigned to work with each student participated. Some evidence suggested that students move significantly away from the professor's point of view after student teaching. There was no significant change of ideas of student teachers toward those of the supervising teachers.

Pickering (265) examined relative effects of inquiry laboratory, inquiry demonstration, or lecture techniques on the prospective elementary teachers' attitudes toward teaching science or attitudes toward different methods of teaching science, and on their science competencies. One-hundred forty-nine prospective elementary teachers participated. Two sections were designated as the inquiry demonstration groups, two as the inquiry laboratory groups, and one as the control group. The major difference in treatment between these groups was student experimentation, student collection of data, and student analysis of data in the inquiry laboratory group as opposed to instructor experimentation, class observation, and class analysis of data through discussion in the inquiry group. There was no significant difference in attitudes towards different methods of teaching science or in science competencies as a result of treatment. ~~However~~, the upper elementary majors were significantly superior to the lower elementary majors on the criteria of science competencies.

The purpose of a study by Staley (330) was to compare the effectiveness of a commonly accepted micro-teaching paradigm with other models believed to be logically more efficient for teacher preparation institutions having large pre-service teacher enrollments, limited instructional and supervisory personnel, and limited amounts of class contact time. The population consisted of 240 pre-service teachers enrolled in an elementary science methods course. The paradigms differed in two respects: number of micro-lessons presented (one or two) and number of pupils in the micro-teaching classes (four, eight, twelve or sixteen peers). Although there were no significant differences found in the teaching behaviors and attitudes of the pre-service teachers, the evidence was not sufficient to indicate equality among the micro-teaching paradigms.

Sylvestre (345) researched the relationship between the attitude of prospective science teachers toward the physical and biological sciences and the college curricula in which they were enrolled. He hypothesized that the attitude toward the sciences from most to least favorable would be: 1) secondary school science, 2) liberal arts science, 3) physical education, and 4) business administration. The population consisted of 116 students enrolled in the four above mentioned curriculum groups. The findings were in agreement except there was a reversal of the attitude scores along the continuum for physical education and business administration majors and a relatively small difference in attitude scores among the four groups. Analysis suggested that positive attitudes toward science were proportional to the number of credit hours completed.

Skinner (314) found no significant increase in critical thinking ability in using a team-taught natural science course with 193 students participating in the study. There was a relationship between positive attitude and increase in critical thinking ability.

Summary. A serious weakness of attitude studies is the lack of adequate instruments for measurement and vagueness about the meaning of attitude. A number of studies inquired into change in attitudes as a result of methods course work. Perhaps this apparent interest is due to expediency and convenience in the availability of a study group for research purposes. Other problems with respect to attitude studies have been mentioned in foregoing sections of this paper.

Teacher Education: Techniques

The following section contains the review of several techniques used in teacher education. The first study by Currie (85) was an investigation to compare the effectiveness of two techniques of teaching a science methods course in secondary education to prospective science teachers. The main difference between the techniques was whether or not teacher aide experience was included. Students who were exposed to such an experience in the methods courses were superior in overall performance of selected teaching procedures. The superiority of the experimental group in overall performance of the selected teaching procedures indicated that the teacher aide experience could be incorporated into the methods course without a disadvantage to the students. However, there was no evidence to support the hypothesis that teacher aide experience would increase the ability of the student teacher to perform any one of the nine selected teaching procedures used in this study.

A study by Fitzgerald (108) included 52 subjects drawn randomly from a population of 165 students in a general methods course immediately preceding the student teaching experience. This investigation was designed to determine the effects of a perceptual modeling concept, presented during pre-service experience on the verbal behavior of students during their teaching experience. The findings of the study indicated that student teachers who received a perceptual modeling concept presentation of interaction analysis during their pre-service training showed significantly different verbal behavior in their classroom performance. These student teachers were more accepting of students' failings, gave more praise and more acceptance and clarification of student ideas, gave less lectures, spent less time in criticizing students, and stimulated more student talk.

The effects of three supervisory methods upon the development of a teaching strategy among science student teachers were tested by James (158). Three groups were used: a traditional group who received visitation and conferences with the university supervisor, a second group which received the same treatment but additionally viewed and discussed films of experienced teachers in the classroom, and a third group which was supplemented by opportunities for each member to evaluate his classroom teaching behavior via video-tape recordings. Findings showed that student teachers who practices self-evaluation via video-tape recordings developed inductive indirect teaching techniques to a greater extent than did students in the other groups.

Irwin (155) investigated the question: "To what extent do the child and the instructional task influence the teaching behavior of pre-service elementary teachers?" Two principal conclusions drawn from this study are: 1) the effect of instruction in the use of interaction analysis in which subjects from all treatment groups participated produced more similarities than differences in changes of the teaching behavior of pre-service elementary teachers of science, and, 2) where differences occurred, the children taught influenced teaching behavior more than did the instructional task.

Strawitz (338) developed an observational system to provide feedback to student teachers in both the affective and cognitive domains in science classes and to explore the effects of using the system for feedback in the training and supervision of secondary science student teachers. There were 13 student teachers involved in this study. At the end of the student teaching experience, student teachers trained and supervised with this system differed significantly from those not so trained in many ways: 1) they used more acceptance and clarification of student ideas, 2) they had more student talk in their classes, 3) they used less teacher factual talk, 4) there was less teacher lecturing, and 5) they placed greater emphasis on the use of supportive and accepting behaviors in comparison to directing and controlling behaviors.

The purposes of Rusch's (289) study were to develop an instructional procedure which would give prospective secondary science teachers alternative verbal behaviors which could be used in lieu of rating behaviors, and to measure this procedure's effectiveness by analyzing, rating, and accepting behaviors of the subjects prior to instruction, after instruction, and the following semester during student teaching. Results showed there was a significant increase in the use of acceptance behavior during student teaching. A significant decrease in the use of praise occurred which persisted in the student teaching. A significant decrease in the use of reinforcement acceptance pairs occurred.

Harris et al. (134) examined the effectiveness of micro-teaching experiences in elementary science methods classes. The micro-teaching experiences were found to be more effective than single teaching experiences in promoting growth of prospective elementary teachers in the following: the use of background information, performance of experiments by children, allowing children to develop conclusions, helping children verify conclusions, and overall response of children to the student teacher.

Beisenherz (29) attempted to determine the degree to which 113 selected skills and techniques were "mastered" by 21 prospective high school biology teachers. Responses indicated that approximately 50 percent of the techniques were acquired during undergraduate preparation. The author suggested a special course should be offered in laboratory techniques.

Summary. An obvious trend in the studies of techniques is a greater concern for humanistic behavior of student teachers. There is also an increase in self-evaluation techniques. Many researchers are utilizing techniques such as video-tapes, interaction analysis, closed circuit television, and micro-teaching. As greater emphasis is put on inquiry teaching methods and use of individualized instruction the human qualities required in effective teaching come to the foreground. Further research is needed on the affective aspects of teacher-pupil interaction.

Teacher Education: Skills and Questioning Techniques

The next three studies are involved with skills such as questioning. Larsen (230) attempted to determine whether prospective elementary school science teachers could be trained to identify the inquiry strategy for teaching science. A second purpose was to determine whether a social substantive schedule or a micro-teaching technique was more effective in training prospective teachers to identify and demonstrate the inquiry strategy of teaching science. Methods students in the study received common training during the first six weeks. During the next seven weeks, 24 students received training in the use of the social substantive schedule. The remaining eight students participated in eight weeks of micro-teaching. Both the social substantive schedule and micro-teaching experience were effective methods for improving the elementary school science teachers' ability to identify teaching strategies. However, no significant difference was found between the micro-teaching technique and the social substantive schedule in increasing prospective elementary school science teachers' ability to identify or demonstrate inquiry strategy.

Blosser (45) investigated the development of the skill of effective questioning by prospective secondary school science teachers. Forty-two pre-service secondary teachers were studied over three academic quarters. Results indicated that questioning appeared to be a skill that could be developed through instruction and practice. The development of questioning skill did not appear to be limited by intelligence, sex, personality type, or educational set.

Konetski (188) reported the results of two instructional strategies on three aspects of pre-service science teacher behaviors: 1) the number of divergent and evaluative questions asked, 2) the proportion of divergent and evaluative questions asked, and 3) the total number of questions asked. Findings were that 1) instruction in classifying and designing questions significantly and positively affected both the number and proportion of divergent and evaluative questions asked, and 2) conferences between the instructor and the student teacher were more effective in affecting the divergent and evaluative questions asked when used with formal instruction.

Teacher Education: Miscellaneous

The first two studies deal with supervision and administration. The first by Pierce (266) attempted to examine the role of science division heads in regionally accredited public and private junior colleges in the United States. Using a survey technique, he found 1) the role of science division heads was relatively uniform, 2) the private department heads were paid markedly lower salaries than public junior college department heads, 3) almost 60 percent had too little time for effective performance of their assigned tasks, and 4) the major obstacles mentioned by science division heads were lack of time and the inability to gain and maintain the confidence of their teaching staff.

Wheat (382) attempted to identify technical skills of science supervisors and to develop a science supervisor technical skills inventory. Technical skills were identified within eight major task areas including leadership, curriculum development, inservice education, science facilities, equipment and materials, science teaching methods, self growth, and public relations. A national jury composed of state science supervisors, local science supervisors, science educators, and directors of National Science Foundation Institutes for science supervisors chose the most important technical skills from an original list. Findings from the study resulted in a list of 180 technical skills of science supervisors which had received the endorsement of 75 percent or more of the national jury. Jury responses placed a higher priority on skills oriented toward the overall supervisory functions and a lower priority on those skills closer to the teaching process.

Sparks (329) attempted to identify problem solving techniques employed by freshmen college biology students and to present implications of problem solvinv techniques for secondary school teachers. Two groups of ten students were selected to participate in the study. One group was designated on the basis of various test scores as successful problem solvers and the other group with the lower scores was designated as unsuccessful problem solvers. Sparks found that the successful students made use of problem solving techniques and arrived at more logically sound and correct conclusions than the unsuccessful students. The unsuccessful subjects attended special 15 minute problem solving practice sessions for five weeks. Upon completion there was a significant difference in their ability to solve problems and their grades increased in the second semester after these sessions.

Mills (227) attempted to explore, through direct and systematic observation, the behavior of pre-service elementary school teachers when solving task-oriented problems. In addition, the effects of critical thinking, cognitive style, and choice of teaching level on problem solving efficiency were analyzed. Analysis indicated that no one strategy was consistenly employed by students when solving task oriented problems which offered alternative solutions. There were no significant effects on problem solving efficiency which could be attributed to critical thinking ability, descriptive part, whole, or relational contextual cognitive styles, or choice of teaching level.

Dee (89) tried to determine whether certain specific scientific knowledge and the ability to identify the process of inductive teaching had an effect upon the ability of 100 future teachers to apply an inductive approach to a classroom situation. He found that a student teacher with knowledge of basic scientific principles and the ability to identify the inductive method had a significantly stronger capability for applying the inductive teaching method than did a student teacher without this knowledge and ability. No relationship was found between a student teacher's ability to identify the inductive teaching method and his tendency to select the most inductive method as having the greatest potential for learning.

Neie (241) investigated the relationship between performance by subjects on science process tasks and ability to comprehend, through contextual clues, the operational meaning of verbal directions specific to these tasks. He concluded that performance by the subjects on selected science process tasks was dependent upon an ability that is related to a general verbal ability, but was not dependent upon the possession of an extensive science vocabulary.

McCormack's (212) study was designed to determine the effects of a modified elementary science education methods course on a student's creative thinking, self-evaluation, and achievement. The experimental group was found superior to the control group in gains of fluency, flexibility, and originality. No difference was found between groups in achievement scores. There were no significant differences between groups in self-ratings of achievement of cognitive course objectives. The findings suggest that creativity can be improved.

Nickel (247), using interaction analysis examined the relationship between student teachers and cooperating teachers. Twenty-three secondary science student teachers and their cooperating teachers were observed. The verbal interaction was encoded using the verbal interaction category system. He concluded that student teachers emulated verbal behaviors of their cooperating teachers, implying the need for teacher training institutions to expand the role of the cooperating teacher in shaping the behavior of the student teacher.

Bender (33) studied the human reproduction knowledge of 163 prospective elementary teachers. Some of the conclusions included: 1) the sampled teachers were poorly prepared in terms of sexual knowledge; 2) factors such as father's occupation, type of community, educational specialization level, had no appreciable bearing on scores; and 3) factors such as marital status and number of sisters and brothers had an effect on the scores achieved by the respondents.

Weinstock and Crawford (378) attempted to determine the relationship between elementary school teachers' theoretical educational framework and a formal methods course in teaching elementary school science. The initially logically consistent student teachers did not show any change as a result of having the course. The group which had not been logically consistent initially improved significantly.

Summary. One trend of interest is an increasing tendency to concentrate on basic teaching competencies, i.e. inquiry strategy, questioning skills, and problem solving techniques. More research is needed on identification of the basic teaching competencies and instruments to measure them.

Curriculum Development

The following six studies all involve some aspect of curriculum development. The first study by McAda and Westmeyer (210) is a description of a curriculum development project for college instruction in science. Its major purpose was to develop or produce type instructional materials which would utilize two procedures: 1) mechanical devices for presenting routine information, and 2) instructional procedures which allowed students to assume a decision making role. This was a developmental project designed to free the laboratory instructor and give students more choice in planning their work. It was found that students improved in total laboratory proficiency as measured by the Jeffrey Test developed by the school.

Schechter (294) attempted to identify, analyze, and evaluate the actual practices related to curriculum, articulation, and sequential planning, students, and general attitudes towards biological science courses offered by California public junior colleges and to recommend desirable practices regarding biology courses for non-science transfer students. Some recommendations included: 1) an integrated biology course with lab experience covering two semesters for three units per semester or the quarter equivalent, should be offered to non-science transfer students, 2) a core curriculum should be developed for biology majors, and 3) more use should be made of advanced placement examinations. Although separate courses for majors and non-majors were favored, this decision should be left to individual institutions.

Williams (388) made a study of the biology curriculum as an area of instruction in the junior colleges of Alabama. For this study he collected data from literature relating to general biology in the two year college and used a questionnaire completed by the instructors of the introductory biology course employed by two year colleges in the state. Instructors were found to be "reasonably" well prepared, carrying excessive loads, and deficient in relation to membership in professional affiliations and professional activities. The students were claimed to possess unrealistic academic goals in terms of their desire to transfer. Some other problems mentioned were crowded conditions, deficiencies in laboratory equipment, deficiencies in funding for supplies and lack of a consensus among instructors about what constituted appropriate programs of study for general biology in the junior college.

Midili (225), using a sample of 80 students compared the dropouts with persistors in engineering technology programs. The findings of the study indicated that the groups differed significantly with respect to achievement, interest in science, mathematics, and technology and attitude toward mathematics, technology, and engineering. Some of the factors influential in program withdrawal were loss of interest, discouragement with courses, and dissatisfaction with "technology" teachers.

Charlier and Charlier (69) conducted a survey of the course offerings in the earth sciences and geography of 100 colleges and the certification requirements of geography teachers in the 50 states. This study of college freshmen revealed widespread ignorance of geographic concepts. The authors stressed the need for better teacher education programs in geography.

Chappell (66) created a model for predicting the unit cost of developing self-instructional materials in higher education biology and physical science. The costs not accounted for in these predictions included development of objectives, selection of appropriate instructional strategies, and the involvement of non-development faculty and staff to the extent that optimal use of the self-instructional materials could occur once they were developed.

Summary. Many of the studies in curriculum development tend to be local in nature and would be of minimal interest to other regions. More research should be done in the area of technology. Many community colleges are finding their technology areas have a high dropout rate and are very expensive programs to operate. The literature is devoid of significant systematic research on the technological impact of community college instruction.

Developmental Studies

Leyden (205) designed a laboratory-oriented college course in environmental geology. His purpose was to design a beginning course in geology which not only accented the sociological implications inherent in the study of geology, but also presented the learner with the opportunity to solve geologic problems by using laboratory techniques. Leyden used five conceptual schemes which he considered essential to the study of environmental geology. A unique part of his study was an attempt to find out, by rating system, which of the activities and projects he suggested were the most efficient for the time involved. Leyden asked three science educators and three geologists to rate each of the activities and projects as efficient use of time, neutral use of time, or inappropriate for the course. Results from the panel of reviewers were included in his project.

The second developmental dissertation describes a systems approach for designing carrel experiences for science students. This study by Russell (290) included a brief history of science carrels dating from 1961 and Postlethwaite's work at Purdue University. Because of the need for many teachers to develop materials for use in science carrels, a model was developed and described which offers a logical sequence and structure for instructional decisions. The author, after field testing, put forth several recommendations, among which were: 1) school systems should provide released time for teachers to develop science carrels, 2) all teachers should be required to take fundamental courses in the area of instructional development, including programmed instruction and carrel design, and 3) schools of education and audio-visual departments should prepare instructional technologists to design learning carrel activities.

Evaluation Studies

Bredemeier (50) developed and validated a particular science related process hierarchy. The students taking part in the validation of the initial hierarchy were 80 prospective elementary teachers. Validation with respect to the effectiveness of the learning sequence was carried out by comparing proportions of students successful in performing each task before and after instructions. For no hierarchy task was there a significant improvementon both test exercises following presentation of a learning sequence.

Eisenstat (102) compared student achievement under two different methods of testing, using surprise tests in one case and announced tests in the other. Some of the findings include: student achievement was significantly higher under a surprise test system in general college math, life science, and world geography. In physical science there was no significant difference in achievement between groups. Analysis of the questionnaire revealed that most students did not like surprise tests. Most students felt surprise tests forced them to keep up-to-date, but they believed they would have kept up-to-date even under an announced test system. Students reported that preparation for surprise test classes was no more time consuming than preparation for announced test classes.

Schell (295) attempted to determine the relative effectiveness of interim testing in using programmed material on achievement and retention among college students. The population included 68 students enrolled in general science for in-training teachers. He concluded that interim testing when used in conjunction with programmed instruction made a significant difference on intermediate achievement as well as on retention.

Zeimet (400) wished to see if color two by two projection slides could be used as substitutes in zoological laboratories for the conventional musical chairs type of practical examination and if so, if there would be a saving of instructor's time. No significant difference in achievement was found between the conventional and projection groups. Some conclusions were: 1) it would be more difficult for students, if so inclined, to cheat on a projection practical, 2) student attitudes toward the conventional or projection method were definitely affected by subject matter, 3) more students made higher scores on projection tests than on conventional tests, 4) use of projection tests could result in a great saving of instructor's preparation time, and 5) the main reason more college instructors do not use projection slides in testing is their belief that the manipulative process is necessary for learning.

Student and Teacher Characteristics

The following five studies deal with student and teacher characteristics. Raina (272) investigated what prospective science teachers believe are the most desirable and least desirable traits of an ideal pupil. The population involved 40 science education students in a regional college of education in India. Raina found that while males and females differed in their perceptions regarding the most valued traits of an ideal pupil, there were no significant differences between the two groups regarding the least desired traits. There was complete variation between the perceptions of the "creativity experts" and the prospective science teachers. Raina concluded that the prospective science teachers would encourage conformity, obedience, and non-creativity.

The purpose of a study by Ault (18) was to determine the effect of students' initial attitude towards science and science instruction, sex, and educational set on success with programmed instructional materials on the basic gas laws. The research indicated that: 1) programmed instruction could be used to teach basic gas laws to general education chemistry students, 2) cognitive style did not influence achievement resulting from the instruction presented in this study, 3) some evidence that the attitude of the individual influenced success on the criterion test, and 4) a possible relationship between sex favoring the male population, and the attitude of the individual toward science and science education.

In a study by Spangenberg (328) the problem was to determine the relationships between academic achievement, student attitude, and verbal interactions of students as they worked in a zoology laboratory. Tape recordings of student conversations in the laboratory were analyzed to determine the percentage of laboratory time spent in lesson-centered discussion, irrelevant discussion, questioning, teacher-talk and silence. Some conclusions which were drawn from this investigation include: 1) high academic achievement was associated with positive student attitude toward a course in general zoology, 2) students who held positive attitudes toward a course in general zoology asked more questions in the laboratory and engaged in the least amount of student laboratory talk, and 3) a student's class rank or attitude toward the class did not influence the amount of help an instructor gave to a student.

In a study by Roberts and Blankenship (283),a sample of 108 elementary student teachers were administered the Pupil Control Ideology Form (PCI Form) before and after student teaching. The student teachers' perceptions of their cooperating teacher's pupil control ideology were measured, using a modification of the same form. This study pointed out that the Pupil Control Ideology of student teachers as a group became significantly more custodial during student teaching. Findings indicated that if a student felt threatened, unless students were rigidly controlled, effective use of inquiry curriculum materials was reduced.

McKinnon (214) dealt with the influence of a college inquiry centered course in science on student entry into the formal operational stage. Five tasks designed to determine whether the student did think logically when presented with problems were given to students. This study found that 51 percent of those students initially tested were operating at Piaget's lowest level of operational thought (concrete), with another 27 percent not having attained his criteria for formal thought. It was reported that the newly developed inquiry oriented science course had an appreciable effect upon students' capacity to think logically.

Summary. Many of these studies reflected an increasing interest in the student as a person and his perception of the learning environment. Other than McKinnon's study, little has been done with Piagetian studies on the college level. With recognition that the formal operational level of thinking may in many cases be delayed until late high school or early college years, additional Piagetian research should be initiated at those instructional levels.

Students' Reactions to Science

There are two studies dealing with the students' reactions to science. The first by Ballard (24) was to determine if there were changes in reactions of beginning college biology students to biology and biologists from 1955-1968, if there have been changes in these reactions during the past 13 years and if these changes related to the type of biology course the student had in high school. He used a questionnaire administered to 223 beginning biology students. Their responses were compared with a similar group of 460 students in 1955. Results of the study tended to indicate that progress has been made in increasing the awareness of high school biology students as well as students in general, of the importance of biology and the work of biologists, better understanding of certain theories and concepts, and a more realistic understanding of the complexity of biology.

Wood (395) examined the concept of the nature and processes of science held by college students enrolled in elementary and secondary education. The secondary science education students scored significantly higher than did primary or intermediate education students. Little relationship was identified between sex, number of university science courses and years of high school science and knowledge of the nature and processes of science.

High School Preparation and College Achievement

The following four studies all deal with the relationship between high school preparation and college achievement. Three of these compare the college achievement of students who used various curriculum projects in high school with those who did not. Tamir (347) was critical of using enrollment data to determine success of BSCS courses versus traditional courses. He reported that if various sources were studied, different information was obtained, so he questioned the reliability of these data. He stated that studies of college students who differ in high school preparation are still needed but such studies would be far more fruitful if they concerned themselves with specific questions as well as with careful analysis of relevant variables in their interactions instead of measuring and only general achievement. Some of his findings showed that BSCS students compared with traditional students were less likely to fail or drop out of introductory biology; among the BSCS versions (blue) students showed the highest rates of failure and attrition, but (yellow) students rarely failed or dropped out. Students who had a laboratory block in high school achieved and gained in college introductory biology significantly more than did students without a laboratory block. Yellow version students had the most positive and blue version students the least positive attitudes towards biology based on their criteria.

Kruglak (195) analyzed pre- and post-Sputnik physics background of 700 high school students. He made a comparison of 1958, 1963, and 1968 knowledge of physics as shown by the Dunning Physics Test. He concluded there were no significant differences due to school size; method of instruction, traditional versus PCCS course; or student rating of teachers' qualifications. The 1963 group was found to be far superior to the 1958 and 1968 groups. Male achievement was significantly higher in all years.

Granger and Yager (123) attempted to determine if BSCS and non-BSCS high school programs prepared the general liberal arts students equally well for a typical introductory biology course at the college level. Also, an attempt was made to compare attitudes towards biological science with regard to type of high school background. The population included 299 university students completing the first semester of introductory biological life science. There were no significant differences found between BSCS and non-BSCS students in achievement in high school or college level biology. The BSCS course was found to generate more favorable attitudes toward biology.

A study by Cottingham (83) had as its major purpose to measure the differences between the levels of achievement of freshmen general chemistry students as related to the type of high school chemistry curricula they had experienced. The two types of high school chemistry curricula studied were the CHEM study and the traditional programs. Findings indicated 1) that there was a statistically significant difference between the achievement of the CHEM study and the traditional groups on the achievement test which favored the CHEM study group,) there was also a significant difference between the college grades favoring the CHEM study group, and 3) there was no significant difference between high school grades earned by the two groups.

Comparative Studies: Laboratory Programs

Following is a group of comparative studies. The first minor category contains seven studies involving the laboratory program. The first of these, by Stekel (334), compared the effectiveness of two different laboratory programs in a college physical science course. The traditional laboratory program in which the students performed exercises from a laboratory manual was used as a control. The experimental group emphasized student involvement in problem selection and experimental design. There were two teachers and 186 students involved in this study. The results showed the laboratory program affected significantly the students' understanding of the actions or operations of the scientists. There was no significant difference found in the students' critical thinking ability, attitude towards science, or retention of selected science concepts. An attitude retention survey implied greater satisfaction when students were given more opportunities to investigate problems of interest.

Bybee (57) evaluated the relative effectiveness of two approaches to a general education earth science course at the college level. The experimental group of 30 students was exposed to an individualized laboratory while the control group received the lecture-demonstration approach. No significant difference in achievement was found, but the experimental group showed increased interest in science.

Chrouser (71) investigated and compared outdoor and indoor laboratory approaches in biology upon prospective elementary teachers in their understanding of the social aspects of science, achievement in selected biological principles, understanding of science as process, and ability in critical thinking. The population consisted of students enrolled in a biology course designed for prospective elementary teachers. Results showed the two groups differed significantly in the specific biological principles in the laboratory activities and in the understanding of science as process. The tests for the biological principles in general and critical thinking showed no significant difference.

Hoff (144) attempted to compare the relative effectiveness of three different approaches to the teaching of a college general education astronomy laboratory: a directed approach, an inquiry approach, and a lecture-demonstration approach. Three sections of a general college introductory astronomy course from a medium size midwestern university were used in this study. None of the three approaches was significantly better for achieving and retaining knowledge of facts and concepts. There were significant differences on critical thinking, subject preference, and transfer. The investigator concluded that inquiry activities should be used in general education astronomy courses to promote critical thinking, subject interest, and participation in science related activities.

Godomsky (121) endeavored to determine the effectiveness of experiments without explicit directions, programming of prerequisite capabilities for each of four basic experiments, and using performance problems programmed for computer evaluation. Results on performance tests used in this study indicate that the design of laboratory instruction increased the student's problem solving ability in physical chemistry and that the laboratory could be a valuable instructional technique in chemistry if the experiments were genuine problems without explicit directions.

Richardson and Renner (280) compared the performance of college students in an inquiry approach chemistry laboratory to those in a conventional laboratory. The study showed the inquiry method to be superior on the laboratory examinations used.

Comparative Studies: Methods of Teaching

This group of comparative studies is concerned with teaching methods. The first study by Smith (317) was a comparative study of two methods of teaching physical science to college freshmen from disadvantaged backgrounds. This study compared the effectiveness of an experimental student-centered method to a traditional method of teaching physical science to disadvantaged college freshmen. The experimental group scored significantly higher on understanding of the methods and nature of science and the ability to think critically in non-scientific areas.

Harvey (136) attempted to determine the effect of the playing of a science learning game on the cognitive and affective process learning of black graduate students in elementary education. A concurrent treatment group using a lecture-discussion format was used as the control. The results indicated significantly superior post-test results in achievement in science, attitude toward science, confidence in science, and the learning of specific concepts taught in the game for the experimental gaming group as compared to the lecture-discussion control group. An important finding of this study was that low achievers in science benefit most from the gaming strategy.

Nimen (248) attempted to develop and test a set of materials that explored sophisticated physical ideas through the use of mathematical models as to the achievement in three areas: the understanding of physical science, critical thinking, and the knowledge of the processes of science. The experiment included 76 liberal arts students. The students of the experimental group, having the basic curriculum supplied by a mathematics models text, performed significantly better on the physics test than did the control group. The critical thinking and the knowledge of processes of science showed no significant differences.

Schlicting and Brown (298) were interested in the effect of background music on student performance. They used 225 students and alternated a series of 12 lectures and one hour examinations all with background music with a similar series in which background music was lacking. Their results showed a significant difference in grades in the group which had background music. There was a 4.6 percent improvement of grades. They found the type of music was very important as to its effect. The students preferred in order given: soft jazz, semi-classical, slow popular music, and instrumental type music.

In a study by Collier (79), the problem was to determine the relative effectiveness of the note test system and the traditional lecture system of teaching basic college chemistry. As a result of the experiment, it was concluded that neither system of teaching basic college chemistry was superior to the other in bringing about student achievement or increasing critical thinking ability. However, the note test system of teaching appeared to have a better chance of success than the traditional lecture system in bringing about achievement when used with high and medium ability students. Low ability students seemed to do better under the traditional system. It appeared that the note test system of teaching was superior to the traditional lecture system in producing high positive attitudes among students in all ability levels toward the basic college chemistry course.

Bell (30) examined the effectiveness of the three lecture per week method of teaching general education biology with six alternative approaches involving various reductions in weekly class attendance. In three of the experimental groups, lectures were reduced in number and supplemented by readings, quiz sessions, or study guides. In the other three, attendance at lectures was not required, students were assigned readings, met in seminars, or were tutored by other students. Tape recordings of lectures and review sessions were available to all students. No significant differences were found on the attitude measures. On the final content test all experimental groups achieved significantly higher than the control section. It was noted that the students' expressed approval of an instructional method was not always supported by their use of the method when available.

Chanin (65) investigated the relative effectiveness of two scheduling patterns, using 614 students enrolled in an introductory biology course. The main variable was the length and placement of the laboratory period in relation to the lecture. While both groups met twice per week for lecture, the control group had one three hour laboratory per week and the experimental group had two one and one-half hour laboratories per week, each period immediately following the lecture. The contiguous semi-weekly scheduling pattern (experimental) proved to be significantly superior to the non-contiguous weekly scheduling pattern (control) in reference to student achievement in the understanding of biological knowledge and the ability to apply this knowledge to the solution of problems. With respect to achievement in the ability to think critically, each proved equally effective.

Wells' (381) study was used to determine whether general concepts which are commonly taught by motion pictures could be learned as effectively by sequential still photographs. There were three modes used: motion pictures, slides, and sequential still photographs. When all the test scores were combined across the study programs to analyze the total effectiveness of the three modes of presentation, the analysis failed to find any significant differences. Therefore, it was the conclusion of the author of the study, that although certain media were most effective in presenting specific concepts, learning did occur with each of the three media. Hence, the choice would not only be based on effectiveness in learning but also upon other educational decisions such as availability, portability, expense, and study time required.

Reed (277) compared the effectiveness of the planetarium and the classroom chalkboard and the celestial globe in the teaching of specific astronomical concepts. He used approximately 800 students enrolled in a one semester basic physical science course. In each semester, the students were randomly divided into two groups. One group received the chalkboard globe presentation while the other group received the planetarium presentation of the same astronomical concepts. On the basis of his tests, Reed concluded that the chalkboard globe teaching situation was significantly superior to the planetarium teaching situation with respect to the immediate attainment and retention of specific cognitive behavioral objectives. There was no difference in the affective domain between chalkboard globe teaching situations and the planetarium teaching situation.

Comparative Studies: Programmed Instruction and CAI

The studies in this section are all concerned with some form of programmed instruction. The major group was concerned with audio-tutorial methods while some of the final studies were concerned with computer assisted instruction. Husband (153) utilized the A-T approach to answer the question, "Does the threat of a grade in the oral quiz session have an effect on the amount of subject matter learned?" The experimental design involved three randomly chosen treatment groups. In the first group there was an oral grade given where the instructor selected which student was to respond. In the second group there was no oral grade given, the instructor still selecting which student was to respond. In the last group there was no oral grade given and students were allowed to volunteer rather than be selected to respond. An analysis of the data indicated that there was no significant difference in achievement between the three treatment groups.

Nord (249) attempted to assess the effect of attendance requirements on achievement in audio-tutorial college biology. Attendance was compulsory for the 154 members of the experimental group and for 153 control group subjects it was non-compulsory. Analysis showed no significant difference between control and experimental group achievement for either group. Approximately one-half of the experimental group thought required attendance had worked to their advantage and recommended it for future classes. Only one-fifth of the control group were of this opinion.

Another study involving A-T techniques was done by Sieramkowski (312). The hypothesis he attempted to test was whether the auto-paced teaching process was superior to conventional instructions in terms of 1) achievement in a physical science course, 2) attitudes of students towards physical science, 3) understanding the nature and processes of science, 4) ability to do elementary school science teaching unit plans, and 5) time required by students to complete assignments in the course. The auto-paced teaching process combined methods used in team teaching, large group instruction, programmed learning, and audio-tutorial independent study. As one result, the auto-paced group took 28 percent less time to complete the assigned tasks, yet achieved as well as or better than the control group, indicating this was a more efficient teaching method.

The next two studies are involved with programmed and computer assisted instruction. Castleberry (63) studied the development and evaluation of computer assisted instruction programs on selected topics in introductory college chemistry. Data showed that the computer assisted instruction programs aided the acquisition of the behavioral objectives and had a significant effect on the final examination score. Some confounding factors of test reliability and validity limited generalization from the data.

Young (399) compared supplementary programmed and conventional methods of instruction in teaching freshman chemistry. The population for the study consisted of 321 students, of whom 114 were in the experimental group and 207 were in the control group. No significant difference in achievement was found for the groups. Students achieved higher on cumulative and minimum attainment tests when supplementary programmed materials were used in general chemistry. Responses indicated that the majority of students reacted favorably to the supplementary programmed materials.

Comparative Studies: Behavioral Objectives

The last three comparative studies to be reported involve behavioral objectives. Merrill (223) investigated the effects of the availability of behaviorally stated objectives on the learning process. The presentation of objectives was expected to reduce the number of examples and the amount of time required to learn the task, facilitate performance on transfer-retrieval criterion measures and reduce the requirement for memory and reasoning abilities. On the basis of the results of this study, it was concluded that objectives had orienting and organizing effects which disposed students to attend to, to process, and to structure relevant information in accordance with the given objectives.

Boardman (46) designed his study to test whether an advanced knowledge of behavioral objectives would enhance students' learning. Three remedial chemistry classes were randomly divided into four groups. Group A received packets containing behavioral objectives relating to the unit under study and attended lecture and laboratory. Group B received packets containing behavioral objectives but did not attend lecture and laboratory. Group C received packets containing a paragraph on a chemical topic unrelated to the material under study (a placebo). This group attended lecture and laboratory. Group D received packets containing placebos but did not attend lecture and laboratory. Analysis of variance showed no significant difference in the achievement among students who received behavioral objectives whether they attended lecture and laboratory or whether they did not. Also, there was no significant difference in the achievement of students who received a placebo whether or not they attended lecture and laboratory. There was no significant difference between groups with behavioral objectives and those without.

Cook (81) investigated the question, "If a group of students is informed of the behavioral objectives in the learning hierarchy of a unit of instruction and another group of students receiving the same unit of instruction is not so informed, will there be differences in effect on learning and retention?" Eighty-eight elementary education majors in a four year college were blocked on ability levels and randomly assigned to four treatments. While receiving different information about the behavioral objectives in the hierarchical learning sequences, all four groups received the same set of self-instructional text materials covering a mathematical unit of instruction. There were no significant differences resulting from the four treatments on student overall performance. However, the four treatments resulted in significantly different rates of forgetting. Group scores of students who were given statements of each activities' objective showed a positive gain in performance over time. However, the results of this study do not support the thesis that informing students of the behavioral objectives and/or learning hierarchy could enhance their performance on an immediate achievement test.

Summary. The major observation of the comparative studies is that researchers are trying new things and attempting to test them. Many result in "no signiffcant difference," but this may be because we are presently unable to measure the differences. Also, the affective areas are being stressed much more. The trend seems to be to offer several alternatives to students since there appear to be no significant difference in the results.

SUMMARY

Research in science education in 1970 was characterized by great variety and an abundance of studies. It appears that the quantity of research in the field increased markedly (total of 403 studies in 1970 versus 475 studies in two previous years--1968-69). Approximately one-sixth of the 1970 studies dealt with some aspect of new curriculum projects, mainly at the elementary and secondary levels.

Areas of individualization of instruction, Piaget studies, attitude measurement, inquiry teaching, and interaction analysis received increased attention, while the traditional areas of curriculum, teaching methods, and evaluation continued at a high level.

An honest assessment of the quality of the research efforts can only yield disappointing conclusions. The majority of research is short-term, localized, and of questionable value in the overall advancement of more effective science education. Over seventy percent of the studies were first efforts (doctoral dissertations). While this statement is not meant to demean the quality of dissertation research generally, it is nevertheless true that such studies are frequently based on small samples, attack small scale problems of a specific nature, and in many cases reply upon investigator-developed instruments the reliability and validity of which may be suspect.

At the same time, it is encouraging to note the obvious growth of interest in science education research as indicated by the proliferation of studies in the past few years. Also, the type of problems being attacked has broadened to include areas considered nebulous or too difficult in the past, such as attitude assessment, creativity measurement, and teacher-pupil interactions. This is a healthy sign and indicates a vigor which has potential for growth and development in uncharted directions of science education research for the future.

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